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RESEARCH MEMORANDUM

THEORETICAL PERFORMANCE OF LIQUID AMMONIA WITH LIQUID OXYGEN AS A ROCKET PROPELLANT

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NATIONAL ADVISORY COMMITTEE
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SUMMARY

Theoretical rocket performance for both equilibrium and frozen composition during expansion was calculated for the propellant combination liquid ammonia with liquid oxygen at two chamber pressures (300 and 600 lb/sq in. abs) and a wide range of pressure ratios (1 to 1500) and oxidant-fuel ratios (0.564 to 7.046). Data are given to estimate performance parameters at chamber pressures other than 300 and 600 pounds per square inch absolute. The parameters included are specific impulse, specific impulse in vacuum, combustion-chamber temperature, nozzle-exit temperature, molecular weight, molecular-weight derivatives, characteristic velocity, coefficient of thrust, ratio of nozzle-exit area to throat area, specific heat at constant pressure, isentropic exponent, viscosity, thermal conductivity, Mach number, and equilibrium gas compositions.

The maximum value of specific impulse for a chamber pressure of 600 pounds per square inch and an exit pressure of 1 atmosphere (pressure ratio, 40.827) is 278.7 and 269.3 assuming equilibrium and frozen composition, respectively.

INTRODUCTION

The performance of ammonia and oxygen as a rocket propellant has been reported in the literature (e.g., refs. 1 to 3). However, additional performance calculations based on the latest thermodynamic data are needed for a wider range of conditions than were heretofore available. Calculations were therefore made at the NACA Lewis laboratory to provide rocket performance data for liquid ammonia and liquid oxygen for the following conditions:

(1) Equilibrium and frozen composition during expansion

(2) Two chamber pressures (300 and 600 lb/sq in. abs)

(3) A wide range of oxidant-fuel weight ratios (0.564 to 7.046)

(4) A wide range of pressure ratio (1 to 1500)

Data are given to permit estimates of performance parameters at chamber pressures other than 300 and 600 pounds per square inch absolute.

SYMBOLS

A	nozzle area, sq in.
$\mathscr{A}$	number of formula weights (defined as A in ref. 4)
a	local velocity of sound, ft/sec
C_F	coefficient of thrust; $C_F = g_c I/c^* = F/P_c A_t$
C_p^o	molar specific heat at constant pressure, cal/(mole)(°K)
c_p	specific heat at constant pressure, $(\partial h/\partial T)_p$, cal/(g)(°K)
c_v	specific heat at constant volume, cal/(g)(°K)
c^*	characteristic velocity, $g_c P_c A_t/w$, ft/sec
F	thrust, lb
$f_\mu^{(k)}$	function of force constant ε/k and temperature T
g_c	gravitational conversion factor, 32.174 (lb mass/lb force)(ft/sec^2)
H_T^o	sum of sensible enthalpy and chemical energy at temperature T, cal/mole
h	sum of sensible enthalpy and chemical energy per unit mass, $\dfrac{\sum_i x_i (H_T^o)_i}{\mathscr{M}}$, cal/g
I	specific impulse with ambient and exit pressures equal, (lb force)(sec)/lb mass
I_{vac}	specific impulse in vacuum, (lb force)(sec)/lb mass
k	coefficient of thermal conductivity, cal/(sec)(cm)(°K)

M	Mach number
$\mathscr{M}$	molecular weight, $\sum_i x_i \mathscr{M}_i$, g/g-mole or lb/lb-mole
n_{c^*}	characteristic-velocity exponent, $\frac{\Delta \ln c^*}{\Delta \ln P_c}$ and $\frac{\partial \ln c^*}{\partial \ln P_c}$ for frozen and equilibrium composition, respectively
n_I	specific-impulse exponent for fixed pressure ratio, $\left(\frac{\Delta \ln I}{\Delta \ln P_c}\right)_{P_c/P}$ and $\left(\frac{\partial \ln I}{\partial \ln P_c}\right)_{P_c/P}$ for frozen and equilibrium composition, respectively
n_T	temperature exponent for fixed pressure ratio, $\left(\frac{\Delta \ln T}{\Delta \ln P_c}\right)_{P_c/P}$ and $\left(\frac{\partial \ln T}{\partial \ln P_c}\right)_{P_c/P}$ for frozen and equilibrium composition, respectively
n_ε	area-ratio exponent for fixed pressure ratio, $\left(\frac{\Delta \ln \varepsilon}{\Delta \ln P_c}\right)_{P_c/P}$ and $\left(\frac{\partial \ln \varepsilon}{\partial \ln P_c}\right)_{P_c/P}$ for frozen and equilibrium composition, respectively
O/F	oxidant-fuel weight ratio
P	static pressure (sum of partial pressures), lb/sq in.
p	partial pressure, lb/sq in.
Q	heat of formation or dissociation
R	equivalence ratio, ratio of two times the number of oxygen atoms to the number of hydrogen atoms, 2(O)/(H)
$\mathscr{R}$	universal gas constant (consistent units)
S_T^o	entropy at a pressure of 1 atm, cal/(mole)(°K)
s	entropy per unit mass, $\frac{\sum_i x_i\left[(S_T^o)_i - \mathscr{R}\ln(p_i/14.696)\right]}{\mathscr{M}}$, cal/(g)(°K)

T	temperature, °K
V	velocity, ft/sec
v	specific volume
w	mass-flow rate, lb/sec
x	mole fraction
γ	isentropic exponent, $\left(\frac{\partial \ln P}{\partial \ln \rho}\right)_s$
ε	ratio of nozzle area to throat area
ε/k	force constant for viscosity calculation
μ	absolute viscosity, g/(cm)(sec) or poises
ρ	density, lb/cu in.
σ	collision diameter for viscosity calculation
$\Omega^{(2,2)^*}$	function of force constant ε/k and temperature T

Subscripts:

c	combustion chamber
e	nozzle exit
i	product of combustion
inj	injector
P_c/P	constant pressure ratio
p	constant pressure
s	constant entropy
T	constant temperature
t	nozzle throat
1	reference point

Superscript:

o thermodynamic standard reference state

CALCULATION OF PERFORMANCE DATA

Performance data were obtained for liquid ammonia with liquid oxygen for two chamber pressures over a wide range of oxidant-fuel ratios and pressure ratios assuming both equilibrium and frozen composition during expansion.

The computations were carried out by the method of reference 4 with modifications to adapt it for use with an IBM 650 Magnetic Drum Data-Processing Machine. The machine was operated with floating-decimal-point notation and eight significant figures. The successive-approximation process used in the calculations was continued until seven-figure accuracy was reached in the desired values of the assigned parameters (mass balance, pressure, and enthalpy or entropy).

Assumptions

The calculations were based on the following usual assumptions: perfect gas law, adiabatic combustion at constant pressure, isentropic expansion, no friction, homogeneous mixing, and one-dimensional flow. The products of combustion were assumed to be the following ideal gases: atomic hydrogen H, hydrogen H_2, water H_2O, atomic nitrogen N, nitrogen N_2, nitric oxide NO, atomic oxygen O, oxygen O_2, and the hydroxyl radical OH.

Initial Data

Thermodynamic data. - The ideal gas thermodynamic properties for atomic hydrogen, hydrogen, atomic nitrogen, nitrogen, atomic oxygen, and oxygen were taken from reference 5. Data for water are also given in reference 5; however, the same data are given to more decimal places in reference 6, and therefore reference 6 data were used. Nitric oxide thermodynamic properties were taken from reference 7, and the hydroxyl radical data were taken from reference 8. The values of entropy used in the present report do not include nuclear spin.

Heats of formation or dissociation. - The heats of formation or dissociation for the six molecules considered in this report are given in the following table:

Reaction (all substances in gas phase)	Heat of formation or dissociation, Q		Temperature of reaction, °K	Reference
	cm^{-1}	cal/mole		
$Q + H_2 \rightarrow 2H$	36,116	103,263	0	9
$Q + N_2 \rightarrow 2N$	[a]78,747	225,154	0	10
$Q + O_2 \rightarrow 2O$	41,260	117,971	0	11
$H_2 + \frac{1}{2}O_2 \rightarrow H_2O + Q$	---------	57,797.9	298.16	12
$Q + \frac{1}{2}N_2 + \frac{1}{2}O_2 \rightarrow NO$	---------	21,600	298.16	12
$Q + OH \rightarrow O + H$	37,340.25	106,764	0	13

[a] The value of 78,747 cm^{-1} for N_2 was obtained from the difference in the predissociation limit in $c^3\Pi\mu$ of N_2 (97,970 cm^{-1}) and the ^2D term of N (19,223 cm^{-1}) given in reference 10.

Where values are given in cm^{-1}, the conversion factor used was 1 cm^{-1} = 2.85921 cal/mole, calculated from data given in reference 14. The base used in this report for assigning absolute values to enthalpy is the same as in reference 4.

Viscosity data. - Viscosity data are needed for heat-transfer calculations; however, accurate data for gases at high temperatures are unavailable in the literature. Theoretical considerations of force fields lead to theoretical expressions for viscosity that fit available experimental data fairly well and therefore provide a basis upon which experimental data may be extrapolated into the higher temperature regions. However, the extrapolated data must be considered only as estimates.

The derivations of various theoretical equations for viscosity are treated in detail in references 15 and 16. The use of these equations to obtain a refined numerical calculation of viscosity involves the selection of a force-field potential and considerable numerical work. Much of this numerical work can be saved by using tables of collision integrals such as those based on the Lennard-Jones 6-12 potential and the following equation (ref. 16):

$$\mu \times 10^7 = \frac{266.93\sqrt{\mathcal{M}T}\, f_\mu^{(k)}}{\sigma^2 \Omega^{(2,2)*}} \qquad (1)$$

The parameters $\Omega^{(2,2)*}$ and $f_\mu^{(k)}$ are tabulated in reference 16 as functions of the force constant ε/k and temperature T.

The force constants ε/k and σ for H_2, O_2, N_2, NO, and H were taken from the literature or calculated from experimental viscosity data. No experimental viscosity data were found for N, O, and OH. Values of σ for N and O were estimated from data in reference 17. The value of σ for OH was estimated from

$$\sigma_{OH} = \sigma_O + \sigma_H \tag{2}$$

The values of ε/k for N, O, and OH were estimated as follows:

$$\frac{(\varepsilon/k)_N}{(\varepsilon/k)_{N_2}} = \frac{(\varepsilon/k)_O}{(\varepsilon/k)_{O_2}} = \frac{(\varepsilon/k)_H}{(\varepsilon/k)_{H_2}} \tag{3}$$

and

$$(\varepsilon/k)_{OH} = \sqrt{(\varepsilon/k)_O(\varepsilon/k)_H} \tag{4}$$

Water is a polar molecule, and therefore the $\Omega^{(2,2)*}$ values based on the Lennard-Jones 6-12 potential are not very satisfactory for calculating the viscosity of water. The following equations from reference 18 were used to calculate the viscosity of water up to 1500° K:

$$\mu\times10^7 = 3.61T - 102 \qquad (T\leq 865^\circ\ K) \tag{5}$$

$$\mu\times10^7 = \frac{393.7T^{3/2}}{3315 - T + 0.001158T^2} \qquad (865^\circ\ K< T\leq 1500^\circ\ K) \tag{6}$$

Equation (6) is not satisfactory for high temperatures, since it reaches a maximum at about 2500° K after which it gives values of viscosity that decrease with temperature. In order to have a means of extrapolating to higher temperatures, values of σ and ε/k were calculated to be used in estimating viscosity above 1500° K by means of equation (1).

The force constants selected are summarized in the following table:

Substance	σ, $\mathring{A}$	ε/k, °K	Reference
H	2.551	89.3	[a]19
H_2	2.775	70.2	[a]5
H_2O	[b]3.031	[b]302.2	[a]18
N	3.355	93.0	[c]17
N_2	3.778	73.1	[a]5
NO	3.593	94.3	[a]20
O	3.088	127.2	[c]17
O_2	3.499	100.0	5
OH	2.820	106.6	(d)

[a] Calculated from data in reference given.

[b] To be used for $T > 1500°$ K.

[c] σ estimated from data in reference given, and ε/k estimated by means of eq. (3).

[d] σ estimated by means of eq. (2), and ε/k by means of eq. (4).

Physical and thermochemical data. - Several physical and thermochemical properties of the propellants are listed in table I. Additional properties of ammonia may be found in references such as 21 and 22, and properties of oxygen may be found in reference 23.

Formulas

The formulas used in computing the various performance parameters are as follows:

Specific impulse with ambient and exit pressures equal, (lb force)(sec)/lb mass:

$$I = 294.98\sqrt{\frac{h_c - h_e}{1000}} \tag{7}$$

Specific impulse in vacuum, (lb force)(sec)/lb mass:

$$I_{vac} = I + P\left(\frac{A}{w}\right) \tag{8}$$

Nozzle area per unit mass-flow rate, (sq in.)(sec)/lb:

$$\frac{A}{w} = \frac{86.4554T}{P\mathcal{M}I} \tag{9}$$

Throat area per unit mass-flow rate, (sq in.)(sec)/lb:

$$\frac{A_t}{w} = \frac{2781.6T_t}{P_t\mathscr{M}_t a} \tag{10}$$

This equation is derived from the continuity equation and the fact that velocity of flow equals velocity of sound at the throat..

Velocity of sound, ft/sec:

$$a = \sqrt{\left(\frac{\partial P}{\partial \rho}\right)_s} = \sqrt{\frac{P}{\rho}\left(\frac{\partial \ln P}{\partial \ln \rho}\right)_s} = 299.16\sqrt{\left(\frac{T}{\mathscr{M}}\right)\left(\frac{\partial \ln P}{\partial \ln \rho}\right)_s} \tag{11}$$

Characteristic velocity, ft/sec:

$$c^* = g_cP_c\,\frac{A_t}{w} = 32.174P_c\,\frac{A_t}{w} \tag{12}$$

Coefficient of thrust:

$$C_F = \frac{g_cI}{c^*} = \frac{32.174I}{c^*} \tag{13}$$

Ratio of nozzle area to throat area:

$$\varepsilon = \frac{A/w}{A_t/w} \tag{14}$$

Partial derivatives. - The derivatives of the fundamental thermodynamic quantities have many useful applications. Equations (29) to (32) are examples of these applications.

All the relations between first derivatives may be expressed in terms of three arbitrary first derivatives in addition to the fundamental quantities. The three derivatives selected for this report are $(\partial h/\partial T)_P = c_p$, $(\partial \ln \mathscr{M}/\partial \ln T)_P$, and $(\partial \ln \mathscr{M}/\partial \ln P)_T$. Specific heat c_p is needed in heat-transfer calculations, and the other two derivatives are a useful indication of the extent of dissociation.

These derivatives were obtained by means of the following equations:

$$c_p = \frac{1}{P\mathscr{M}T}\left[\sum_i p_i(H_T^0)_i\left(\frac{\partial \ln p_i}{\partial \ln T}\right)_P - \mathscr{A}h\left(\frac{\partial \ln \mathscr{A}}{\partial \ln T}\right)_P + T\sum_i p_i(C_p^0)_i\right] \tag{15}$$

$$\left(\frac{\partial \ln \mathscr{M}}{\partial \ln P}\right)_T = \frac{P}{\sum_i p_i \left(\frac{\partial \ln p_i}{\partial \ln \mathscr{A}}\right)_T} - 1 \tag{16}$$

$$\left(\frac{\partial \ln \mathscr{M}}{\partial \ln T}\right)_p = \left(\frac{\partial \ln \mathscr{A}}{\partial \ln T}\right)_p \tag{17}$$

where $(\partial \ln p_i/\partial \ln T)_p$, $(\partial \ln \mathscr{A}/\partial \ln T)_p$, and $(\partial \ln p_i/\partial \ln \mathscr{A})_T$ are found by matrix methods similar to those described for obtaining $(\partial \ln p_i/\partial \ln T)_s$ in reference 4, and where $\mathscr{A}$ is A in reference 4.

Reference 24 presents a convenient scheme for expressing all first derivatives in terms of $(\partial v/\partial T)_p$, $(\partial v/\partial P)_T$, and $(\partial h/\partial T)_p = c_p$. In order to make use of the tables in reference 24, $(\partial v/\partial T)_p$ and $(\partial v/\partial P)_T$ can be obtained from the derivatives given in this report by means of the following equations:

$$\left(\frac{\partial v}{\partial T}\right)_p = -\frac{v}{T}\left[\left(\frac{\partial \ln \mathscr{M}}{\partial \ln T}\right)_p - 1\right] \tag{18}$$

$$\left(\frac{\partial v}{\partial P}\right)_T = -\frac{v}{T}\left[\left(\frac{\partial \ln \mathscr{M}}{\partial \ln P}\right)_T + 1\right] \tag{19}$$

With the aid of the tables in reference 24 and equations (18) and (19), other first derivatives can be expressed in terms of c_p, $(\partial \ln \mathscr{M}/\partial \ln T)_p$, and $(\partial \ln \mathscr{M}/\partial \ln P)_T$. As an example,

$$\gamma = \left(\frac{\partial \ln P}{\partial \ln \rho}\right)_s = \frac{c_p}{c_p\left[1 + \left(\frac{\partial \ln \mathscr{M}}{\partial \ln P}\right)_T\right] - \frac{\mathscr{R}}{\mathscr{M}}\left[1 - \left(\frac{\partial \ln \mathscr{M}}{\partial \ln T}\right)_p\right]^2} \tag{20}$$

When composition is frozen,

$$\left(\frac{\partial \ln \mathscr{M}}{\partial \ln P}\right)_T = \left(\frac{\partial \ln \mathscr{M}}{\partial \ln T}\right)_p = 0 \tag{21}$$

and

$$\gamma = \frac{c_p}{c_p - \frac{\mathscr{R}}{\mathscr{M}}} = \frac{c_p}{c_v} \tag{22}$$

Viscosity of mixtures. - Viscosities of multicomponent mixtures calculated by rigorous methods (refs. 16 and 25) show excellent agreement with experimental data. However, these calculations involve considerable effort and become increasingly more difficult with increasing number of components. A simpler technique, but one that still involves considerable calculations, is given in reference 26.

The following equation, based on averaging kinematic viscosities, gives approximate results that are often sufficiently accurate for engineering purposes:

$$\mu = \frac{\mathcal{M}}{\sum_i \frac{x_i}{\mu_i \sqrt{\mathcal{M}_i}}} \tag{23}$$

The equation appears adequate until better high-temperature data for the individual components become available.

Conductivity. - Thermal conductivities as well as viscosities are needed in heat-transfer calculations. However, experimental conductivity data are generally even less available than experimental viscosities. Therefore, the Eucken relationship,

$$k = \mu\left(c_p + \frac{5}{4}\frac{\mathcal{R}}{\mathcal{M}}\right) \tag{24}$$

which often gives satisfactory values of conductivity for individual components, is used in this report to estimate the conductivity of gaseous mixtures.

THEORETICAL PERFORMANCE DATA

Tables

The calculated values of the various performance parameters for combustion pressures of 300 and 600 pounds per square inch absolute and for a range of equivalence ratios and exit conditions are given in tables II to V. Table II presents performance data at assigned pressure ratios from 1 to 1500 for equivalence ratios from 0.40 to 5.00 (oxidant-fuel weight ratios from 0.564 to 7.046). Properties at the throat may be found where $\varepsilon = 1.00$. Table III gives various thermodynamic partial derivatives. Equilibrium composition in the combustion chamber and at the assigned exit conditions is given in table IV. Characteristic velocity and summary of the performance parameters at an exit pressure of 1 atmosphere are presented in table V.

Curves

Performance parameters. - The performance parameters are plotted in figures 1 to 7. Curves of specific impulse are presented in figure 1 for assigned pressure ratios as a function of percent by weight of fuel. Combustion temperature and exit temperature for assigned pressure ratios are plotted in figure 2 as functions of percent by weight of fuel, and curves of the ratio of nozzle area to throat area are plotted in figure 3 as functions of percent by weight of fuel for assigned pressure ratios. Figure 4 gives the curves for coefficient of thrust for assigned pressure ratios as a function of percent by weight of fuel; figure 5 presents curves of molecular weight for assigned pressure ratios; and figure 6 presents curves of characteristic velocity as a function of percent by weight of fuel.

Effect of assuming frozen or equilibrium composition during expansion. - Specific impulses based on equilibrium and on frozen composition during expansion to an exit pressure of 1 atmosphere are compared in figure 7. Maximum values of specific impulse based on equilibrium and on frozen composition during expansion are compared in the following table (taken from table II or V):

Chamber pressure, P_c, lb/sq in. abs	Pressure ratio, P_c/P	Equivalence ratio, R, at which I is maximum	Oxidant-fuel weight ratio, O/F	Composition during expansion	Max. specific impulse, I, $\frac{\text{lb-sec}}{\text{lb}}$	Difference in I, %
300	20.414	0.95	1.339	Equilibrium	256.3	3.2
		.90	1.268	Frozen	248.4	
	1500	1.00	1.409	Equilibrium	345.3	6.5
		.90	1.268	Frozen	324.2	
600	40.827	0.975	1.374	Equilibrium	278.7	3.5
		.90	1.268	Frozen	269.3	
	1500	1.00	1.409	Equilibrium	345.7	5.8
		.90	1.268	Frozen	326.6	

The table shows that, for pressure ratios of about 20 to 40, the difference in maximum specific impulse due to equilibrium or frozen composition during expansion is about 3 to 4 percent, while for a pressure ratio of 1500 the difference increases to about 6 percent. The maximum specific impulse occurs nearer the stoichiometric point (R = 1.00) for equilibrium composition than for frozen composition. For frozen composition, maximum specific impulse remains at the same fuel-rich O/F ratio of 1.268 as pressure ratio increases. For equilibrium composition, the maximum specific impulse moves from a slightly fuel-rich ratio at the lower pressure ratios to the stoichiometric mixture ratio at the high pressure ratios.

Effect of Thermodynamic Data

New and revised thermodynamic data are constantly appearing in the literature. The reason for this may be the availability of better spectroscopic data, or a more rigorous use of the spectroscopic data in calculating thermodynamic functions, or possibly a more accurate determination of heat of formation, heat of dissociation, or heat of transition. In a comparison of the performance of various propellants, care must be taken to see that the same thermodynamic data are used, since different data may affect the results.

Several additional calculations were made to determine the effect on performance of using water data from reference 27 rather than that of reference 5 used in this report, and of the heat of dissociation of OH from reference 12 (100,206 cal/mole) rather than that of reference 13 (106,764 cal/mole) used in this report. The results of these calculations are shown in the following table (P_c = 600 lb/sq in. abs):

Equivalence ratio, R	Pressure ratio, P_c/P	Thermodynamic data, this report	H_2O thermodynamic data, ref. 27	OH heat of dissociation, ref. 5	Difference due to H_2O, percent	Difference due to OH, percent
		Combustion temperature, T, °K				
0.7	1	2503.1	2513.4	2508.2	0.41	0.20
1.0	1	2980.5	3044.1	2984.4	2.13	.13
1.5	1	2759.5	2841.0	2764.0	2.95	.16
		Equilibrium specific impulse, I, lb-sec/lb				
0.7	40.827	262.04	262.09	262.11	0.02	0.03
.7	1000	311.36	311.38	311.39	.01	.01
1.0	40.827	278.30	279.46	278.49	.42	.07
1.0	1000	340.79	341.34	340.88	.16	.03
1.5	40.827	250.32	251.56	250.44	.50	.05
1.5	1000	303.05	303.60	303.09	.18	.01
		Frozen specific impulse, I, lb-sec/lb				
0.7	40.827	260.91	261.40	260.95	0.19	0.02
.7	1000	309.76	310.41	309.74	.21	.01
1.0	40.827	267.23	269.58	267.13	.88	.04
1.0	1000	320.54	323.83	320.23	1.03	.10
1.5	40.827	242.74	245.81	242.69	1.26	.02
1.5	1000	290.16	294.39	290.00	1.46	.06

For the three equivalence ratios selected, the effect of the difference in the heat of dissociation of OH (6556 cal/mole) on both specific impulse and combustion temperature was very small. However, the different thermodynamic data for H_2O made a difference of 82° K in the combustion temperature and 3 to 4 (lb)(sec)/lb in frozen specific impulse for the equivalence ratio of 1.5. The effect of different water data was greater on frozen specific impulse than on equilibrium specific impulse.

Effect of Chamber Pressure

By use of suitable exponents, performance parameters can be estimated with good accuracy at chamber pressures other than those given in this report. The logarithmic values of the parameters I, T, ε, and c^* are very nearly linear with the logarithm of chamber pressure for a fixed equivalence ratio and pressure ratio. This linearity permits the data to be represented by means of exponential equations. For frozen composition the exponents can be calculated from data for two chamber pressures according to the following equations:

$$n_I = \left(\frac{\Delta \ln I}{\Delta \ln P_c}\right)_{P_c/P} \tag{25}$$

$$n_T = \left(\frac{\Delta \ln T}{\Delta \ln P_c}\right)_{P_c/P} \tag{26}$$

$$n_\varepsilon = \left(\frac{\Delta \ln \varepsilon}{\Delta \ln P_c}\right)_{P_c/P} \tag{27}$$

$$n_{c^*} = \frac{\Delta \ln c^*}{\Delta \ln P_c} \tag{28}$$

For equilibrium composition, the following analytic expressions were derived that permit the exponents to be computed from data at a single chamber pressure:

$$n_I = \left(\frac{\partial \ln I}{\partial \ln P_c}\right)_{P_c/P} = 86.4554\ \frac{T}{I^2}\left(\frac{1}{\mathscr{M}_c} - \frac{1}{\mathscr{M}}\right) \tag{29}$$

$$n_T = \left(\frac{\partial \ln T}{\partial \ln P_c}\right)_{P_c/P} = \frac{\mathscr{R}}{\mathscr{M} c_p}\left[1 - \left(\frac{\partial \ln \mathscr{M}}{\partial \ln T}\right)_p\right] - \frac{\mathscr{R}}{c_p \mathscr{M}_c} \tag{30}$$

$$n_\varepsilon = \left(\frac{\partial \ln \varepsilon}{\partial \ln P_c}\right)_{P_c/P} = (n_{A/w})_e - (n_{A/w})_t \qquad (31)$$

$$n_{c*} = \frac{\partial \ln c*}{\partial \ln P_c} = 1 + (n_{A/w})_t \qquad (32)$$

where

$$n_{A/w} = \left(\frac{\partial \ln A/w}{\partial \ln P_c}\right)_{P_c/P} = - \frac{\mathscr{R}}{c_p \mathscr{M}_c}\left[1 - \left(\frac{\partial \ln \mathscr{M}}{\partial \ln T}\right)_p\right] - \frac{1}{\gamma} - n_I$$

Equations (25) to (28) and (29) to (32) may be written in the following approximate form:

$$I = I_1 \left(\frac{P_c}{P_{c,1}}\right)^{n_{I,1}} \qquad (33)$$

$$T = T_1 \left(\frac{P_c}{P_{c,1}}\right)^{n_{T,1}} \qquad (34)$$

$$\varepsilon = \varepsilon_1 \left(\frac{P_c}{P_{c,1}}\right)^{n_{\varepsilon,1}} \qquad (35)$$

$$c* = c_1^* \left(\frac{P_c}{P_{c,1}}\right)^{n_{c*,1}} \qquad (36)$$

where $P_{c,1}$ may be selected to be either 300 or 600 pounds per square inch absolute if I_1, T_1, ε_1, c_1^* and their derivatives are the corresponding values for the chamber pressure selected.

The exponents obtained by means of equations (25) to (32) are shown in tables III and V and are plotted in figures 1, 2, 3, and 6.

To illustrate the use of these derivatives, suppose the value of equilibrium specific impulse is desired for a chamber pressure P_c of 1200 pounds per square inch absolute and a pressure ratio P_c/P of 81.65 (exit pressure, 1 atm) for an equivalence ratio R of 0.95 (O/F, 1.339). From figure 1(c) and table III, the value of I at this pressure ratio and equivalence ratio (but for a chamber pressure of 600 lb/sq in. abs) is 295.8, and the value of n_I is 0.0025. From equation (33),

$$I = 295.8 \left(\frac{1200}{600}\right)^{0.0025}$$

$$= 295.8(1.0017)$$

$$= 296.3$$

The parameters obtained by the chamber-pressure correlation and by a direct calculation are compared in the following table (R = 0.95, equilibrium composition during expansion):

Parameter	P_c = 1200 lb/sq in. abs P_e = 1 atm		
	Estimated by correlation	Direct calculation	Difference
I, lb-sec/lb	296.34	296.32	0.02
T_c, °K	3012.8	3011.0	1.8
T_e, °K	1557.9	1558.2	.3
ε	10.272	10.266	.006
c*, ft/sec	5843.0	5841.6	1.4

Values estimated for other equivalence ratios and for pressure ratios from about 150 to 1200 pounds per square inch absolute will probably have small errors of the order of magnitude shown in this table.

Effect of Finite Chamber Area

The use of a combustion chamber of finite cross-sectional area leads to a pressure change during the combustion process. For a cylindrical chamber, the injector face pressure P_{inj} may be found from the following equation for conservation of momentum:

$$P_{inj} = P_1 + \frac{w}{A_1 g_c}(V_1 - V_{inj}) \tag{37}$$

where P_1 and V_1 are the static pressure and velocity at the nozzle entrance, respectively, and V_{inj} is the average velocity of propellant (liquid or gas) in the axial direction when injected. Equation (37) may be written

$$P_{inj} = P_c\left(\frac{P_1}{P_c}\right) + \frac{P_c}{c^*\varepsilon}(I_1 g_c - V_{inj}) \tag{38}$$

where P_c is the stagnation pressure in the nozzle.

The data in tables II and V may be used to evaluate this expression. For example, consider a rocket operating at the stoichiometric ratio with a nozzle stagnation pressure of 600 pounds per square inch absolute and a chamber- to throat-area ratio ε of 2.131 with V_{inj} equal to 100 feet per second. From table II(c), corresponding to the area ratio of 2.131, P_c/P_1 is 1.05 and I is 35.7. From table V, c* is 5788. Therefore, for these conditions, the pressure at the injector face is

$$\begin{aligned} P_{inj} &= 600\left(\frac{1}{1.05}\right) + \frac{600}{5788(2.131)}[(35.7)(32.17) - 100] \\ &= 571.43 + 0.04865(1048) \\ &= 571.4 + 51.0 \\ &= 622.4 \text{ lb/sq in. abs} \end{aligned}$$

SUMMARY OF RESULTS

A theoretical investigation of the performance of liquid ammonia with liquid oxygen was made for the following conditions: (1) equilibrium and frozen composition during expansion, (2) two chamber pressures (300 and 600 lb/sq in. abs), (3) a wide range of oxidant-fuel weight ratios (0.564 to 7.046), and (4) a wide range of pressure ratios (1 to 1500). The results of this investigation showed:

1. The maximum values of specific impulse for a chamber pressure of 300 pounds per square inch absolute and an exit pressure of 1 atmosphere (pressure ratio, 20.414) are 256.3 and 248.4 assuming equilibrium and frozen composition, respectively, a difference of 3.2 percent.

2. The maximum values of specific impulse for a chamber pressure of 600 pounds per square inch and an exit pressure of 1 atmosphere (pressure ratio, 40.827) are 278.7 and 269.3 assuming equilibrium and frozen composition, respectively, a difference of 3.5 percent.

3. The difference between values of specific impulse due to the assumption of equilibrium or frozen composition during expansion is about 6 percent for a pressure ratio of 1500.

4. The maximum value of specific impulse occurs on the slightly fuel-rich side of stoichiometric. For frozen composition during expansion, the maximum value of specific impulse occurs at the same oxidant-fuel weight ratio independent of pressure ratio. For equilibrium composition during

expansion, the maximum value of specific impulse shifts from the slightly fuel-rich side of stoichiometric to stoichiometric as pressure ratios increase.

Lewis Flight Propulsion Laboratory
National Advisory Committee for Aeronautics
Cleveland, Ohio, February 6, 1958

REFERENCES

1. Stosick, A. J.: Liquid Propellants for Rockets. Prog. Rep. 9-9, Jet Prop. Lab., C.I.T., Dec. 3, 1946. (Contract W-04-200-ORD-1482.)

2. Brinkley, S. R., Jr., Smith, R. W., Jr., and Edwards, H. E.: Thermodynamics of the Combustion Products of Ammonia with Oxygen. Rep. PX 3-107/2, U.S. Dept. Interior, Bur. Mines, Feb. 1952. (Contract NA-onr-97-50.)

3. Brinkley, S. R., Jr., Smith, R. W., Jr., and Edwards, H. E.: Thermodynamics of the Combustion Products of Some Fuel-Liquid Oxygen Systems. Rep. PX 3-107/15, U.S. Dept. Interior, Bur. Mines, Sept. 1953. (Contract NA-onr-97-50.)

4. Huff, Vearl N., Gordon, Sanford, and Morrell, Virginia E.: General Method and Thermodynamic Tables for Computation of Equilibrium Composition and Temperature of Chemical Reactions. NACA Rep. 1037, 1951. (Supersedes NACA TN's 2113 and 2161.)

5. Hilsenrath, Joseph, et al.: Tables of Thermal Properties of Gases. Cir. 564, NBS, Nov. 1, 1955.

6. Friedman, Abraham S., and Haar, Lester: High-Speed Machine Computations of Ideal Gas Thermodynamic Functions. I. The Isotopic Water Molecules. Jour. Chem. Phys., vol. 22, no. 12, Dec. 1954, pp. 2051-2058.

7. Glatt, Leonard, Belzer, Jack, and Johnston, Herrick L.: Computation of Thermodynamic Properties of Gases from Spectra. The NO Molecule. TR 316-10 Cryogenic Lab., Dept. Chem. Ohio State Univ., Aug. 15, 1953. (Contract N6onr-225.)

8. Haar, Lester, and Friedman, A. S.: High-Speed Machine Computations of Ideal Gas Thermodynamic Functions. II. The Diatomic Free Radicals of the Isotopic Hydrides of Oxygen and Sulfur. Jour. Chem. Phys., vol. 23, no. 5, May 1955, pp. 869-875.

9. Beutler, H., and Jünger, H. O.: Die Bindungsfestigkeiten im H_2-Molekül. Zs. f. Phys., Bd. 101, Heft 516, July 1936, pp. 304-310.

10. Gaydon, A. G.: Dissociation Energies and Spectra of Diatomic Molecules. Chapman and Hall, Ltd., 1953.

11. Brix, P., and Herzberg, G.: Fine Structure of the Schumann-Runge Bands Near the Convergence Limit and the Dissociation Energy of the Oxygen Molecule. Canadian Jour. Phys., vol. 32, no. 2, Feb. 1954, pp. 110-135.

12. Rossini, Frederick D., et al: Selected Values of Chemical Thermodynamic Properties. Cir. 500, NBS, Feb. 1952.

13. Hornbeck, George A.: Spectroscopic Determination of the Dissociation Energy of the OH Radical. Fifth Symposium (International) on Combustion, Reinhold Pub. Corp., 1955, pp. 790-794.

14. DuMond, Jesse W. M., and Cohen, E. Richard: Least-Squares Adjustment of the Atomic Constants, 1952. Rev. Modern Phys., vol. 25, no. 3, July 1953, pp. 691-708.

15. Chapman, Sydney, and Cowling, T. G.: The Mathematical Theory of Non-Uniform Gases. Second ed., Cambridge Univ. Press, 1952.

16. Hirschfelder, Joseph O., Curtiss, Charles F., and Bird, R. Byron: Molecular Theory of Gases and Liquids. John Wiley & Sons, Inc., 1954.

17. Hirschfelder, Joseph O., and Eliason, Morton A.: The Estimation of the Transport Properties for Electronically Excited Atoms and Molecules. Tech. Rep. WIS-AF-1, Naval Res. Lab., Univ. Wisconsin, May 14, 1956. (Contract AF-33(616)-3414.)

18. Bonilla, Charles F., Brooks, Robert D., and Walker, Philip L., Jr.: The Viscosity of Steam and of Nitrogen at Atmospheric Pressure and High Temperatures. Paper presented at General Discussion on Heat Transfer Conf. (London), Sept. 11-13, 1951.

19. Amdur, I.: Viscosity and Diffusion Coefficients of Atomic Hydrogen and Atomic Deuterium. Jour. Chem. Phys., vol. 4, no. 6, June 1936, pp. 339-343.

20. Krieger, F. J.: The Viscosity of Polar Gases. RM-646, The RAND Corp., July 1, 1951.

21. Anon.: Tables of Thermodynamic Properties of Ammonia. Cir. 142, NBS, Apr. 16, 1923.

22. Anon.: Physical Properties and Thermodynamic Functions of Fuels, Oxidizers, and Products of Combustion. I. Fuels. R-127, The Rand Corp., Jan. 1949.

23. Anon.: Physical Properties and Thermodynamic Functions of Fuels, Oxidizers, and Products of Combustion. II. Oxidizers. R-129, The Rand Corp., Feb. 1949.

24. Bridgman, P. W.: A Complete Collection of Thermodynamic Formulas. Phys. Rev., 2nd. ser., vol. III, no. 4, Apr. 1914, pp. 273-281.

25. Hirschfelder, Joseph O., Bird, R. Byron, and Spotz, Ellen L.: The Transport Properties of Gases and Gaseous Mixtures, II. Chem. Rev., vol. 44, no. 1, Feb. 1949, pp. 205-231.

26. Bromley, L. A., and Wilke, C. R.: Viscosity Behavior of Gases. Ind. and Eng. Chem., vol. 43, no. 7, July 1951, pp. 1641-1648.

27. Glatt, Leonard, Adams, Joan H., and Johnston, Herrick L.: Thermodynamic Properties of the H_2O Molecule from Spectroscopic Data. Tech. Rep. 316-8, Cryogenic Lab., Dept. Chem., Ohio State Univ., June 1, 1953. (Navy Contract N6onr-225, Task Order XII, ONR Proj. NR 085-005.)

28. Hodgman, Charles D.: Handbook of Chemistry and Physics. Thirty-eighth ed., Chem. Rubber Pub. Co., 1956-1957.

29. Washburn, Edward W., ed.: International Critical Tables. Vol. III. McGraw-Hill Book Co., Inc., 1928.

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TABLE I. - PROPERTIES OF LIQUID PROPELLANTS

Properties	Ammonia	Oxygen
Molecular weight, $\mathscr{M}$	17.032	32.00
Density, g/cc	[a]0.68 (at -33.4° C)	[b]1.1415 (at -182.0° C)
Freezing point, °C	[c]-77.76	[c]-218.76
Boiling point, °C	[c]-33.43	[c]-182.97
Enthalpy required to convert liquid at boiling point to gaseous elements at 25° C, kcal/mole	[d]17.14	[d]3.080
Enthalpy of vaporization, kcal/mole	[c]5.581 (at -33.43° C)	[c]1.630 (at -182.97° C)
Enthalpy of fusion, kcal/mole	[c]1.351 (at -77.76° C)	[c]0.106 (at -218.76° C)

[a] Ref. 28.

[b] Ref. 29.

[c] Ref. 12.

[d] Ref. 4.

TABLE II. - THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 1500 FOR LIQUID AMMONIA WITH LIQUID OXYGEN

(a) Combustion-chamber pressure, 300 pounds per square inch absolute; equilibrium composition during isentropic expansion

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Molecular weight, $\mathcal{M}$	Isentropic exponent, γ	Specific heat, c_p, $\frac{cal}{(g)(^{\circ}K)}$	Absolute viscosity, μ, micropoises	Thermal conductivity, k, $\frac{cal}{(sec)(cm)(^{\circ}K)}$	Mach number, M	Specific impulse, I_{vac}, $\frac{(lb)(sec)}{lb}$	Area ratio, ϵ	Thrust coefficient, C_F	Specific impulse, I, $\frac{(lb)(sec)}{lb}$
R = 0.40, PERCENT FUEL = 63.95, O/F = 0.564													
1.00	300.00	1349	3350.2	13.316	1.2956	0.6541	453	0.00038					
1.05	285.71	1334	3340.4	13.316	1.2966	.6524	450	.00038	0.275	326.2	2.226	0.208	29.1
1.60	187.50	1210	3260.5	13.316	1.3053	.6381	421	.00035	.872	177.3	1.015	.650	88.3
1.84	163.21	1171	3235.9	13.316	1.3082	.6335	412	.00034	1.000	176.0	1.000	.712	99.7
2.00	150.00	1148	3221.3	13.316	1.3100	.6306	406	.00033	1.072	176.5	1.004	.756	105.9
10.00	30.00	772	2993.1	13.316	1.3421	.5855	309	.00024	2.149	204.7	2.030	1.258	176.3
20.00	15.00	646	2919.9	13.316	1.3530	.5720	272	.00021	2.569	215.2	3.093	1.381	193.5
20.41	14.70	643	2917.9	13.316	1.3532	.5718	271	.00021	2.581	215.4	3.133	1.384	193.9
40.00	7.50	538	2858.8	13.316	1.3618	.5617	237	.00018	2.998	223.7	4.823	1.476	206.8
40.83	7.35	535	2857.1	13.316	1.3621	.5614	236	.00018	3.010	223.9	4.888	1.478	207.1
80.00	3.75	447	2807.9	13.316	1.3680	.5547	206	.00015	3.447	230.6	7.629	1.550	217.2
100.00	3.00	421	2793.5	13.316	1.3696	.5530	196	.00015	3.597	232.5	8.863	1.571	220.1
200.00	1.50	349	2753.8	13.316	1.3744	.5479	168	.00012	4.083	237.7	14.191	1.626	227.8
300.00	1.00	312	2733.8	13.316	1.3767	.5454	154	.00011	4.383	240.3	18.744	1.653	231.6
500.00	.60	271	2711.6	13.316	1.3791	.5429	136	.00010	4.781	243.2	26.680	1.682	235.7
800.00	.37	238	2693.7	13.316	1.3842	.5377	122	.00009	5.163	245.5	36.978	1.705	239.0
1000.00	.30	224	2686.0	13.316	1.3872	.5347	115	.00008	5.351	246.4	43.187	1.715	240.4
1500.00	.20	200	2673.2	13.316	1.3928	.5291	104	.00007	5.707	248.0	57.266	1.732	242.7
R = 0.50, PERCENT FUEL = 58.67, O/F = 0.705													
1.00	300.00	1784	3075.9	14.516	1.2616	0.6607	555	0.00046					
1.05	285.71	1766	3064.0	14.516	1.2624	.6590	551	.00046	0.279	359.6	2.206	0.206	32.1
1.60	187.50	1617	2966.5	14.516	1.2695	.6450	520	.00042	.882	196.3	1.013	.626	97.5
1.82	165.20	1574	2938.9	14.516	1.2717	.6408	511	.00041	1.000	195.0	1.000	.700	109.2
2.00	150.00	1542	2918.3	14.516	1.2735	.6375	503	.00041	1.083	195.5	1.006	.751	117.1
10.00	30.00	1075	2632.4	14.516	1.3057	.5847	394	.00030	2.149	229.0	2.090	1.260	196.4
20.00	15.00	911	2538.4	14.516	1.3200	.5647	351	.00026	2.555	241.3	3.218	1.387	216.3
20.41	14.70	906	2535.8	14.516	1.3205	.5641	350	.00026	2.567	241.7	3.261	1.390	216.8
40.00	7.50	768	2458.9	14.516	1.3335	.5474	311	.00022	2.967	251.4	5.065	1.486	231.7
40.83	7.35	764	2456.7	14.516	1.3339	.5469	310	.00022	2.979	251.7	5.134	1.489	232.1
80.00	3.75	644	2392.0	14.516	1.3449	.5338	274	.00019	3.396	259.7	8.071	1.565	243.9
100.00	3.00	608	2372.9	14.516	1.3482	.5301	262	.00018	3.539	262.0	9.396	1.586	247.3
200.00	1.50	508	2320.1	14.516	1.3571	.5203	228	.00016	4.003	268.2	15.126	1.645	256.4
300.00	1.00	456	2293.4	14.516	1.3609	.5162	210	.00014	4.292	271.3	20.033	1.674	260.9
500.00	.60	398	2263.6	14.516	1.3652	.5118	188	.00013	4.673	274.8	28.602	1.705	265.9
800.00	.37	351	2239.5	14.516	1.3682	.5087	169	.00012	5.045	277.5	39.757	1.730	269.8
1000.00	.30	330	2229.1	14.516	1.3696	.5073	161	.00011	5.228	278.7	46.508	1.741	271.4
1500.00	.20	296	2211.7	14.516	1.3718	.5051	146	.00010	5.575	280.6	61.884	1.759	274.2
R = 0.60, PERCENT FUEL = 54.19, O/F = 0.845													
1.00	300.00	2169	2843.5	15.708	1.2334	0.6765	639	0.00053					
1.05	285.71	2149	2830.1	15.709	1.2344	.6734	635	.00053	0.282	381.5	2.191	0.204	34.0
1.60	187.50	1982	2720.1	15.713	1.2423	.6514	603	.00049	.890	208.9	1.012	.622	103.6
1.80	166.72	1937	2691.0	15.714	1.2444	.6461	594	.00048	1.000	207.7	1.000	.692	115.2
2.00	150.00	1897	2665.4	15.714	1.2463	.6417	586	.00047	1.091	208.3	1.007	.748	124.5
10.00	30.00	1361	2336.0	15.716	1.2746	.5870	469	.00035	2.151	245.8	2.140	1.262	210.1
20.00	15.00	1169	2225.3	15.716	1.2883	.5650	422	.00031	2.548	259.7	3.331	1.393	231.9
20.41	14.70	1164	2222.3	15.716	1.2888	.5643	421	.00030	2.560	260.0	3.376	1.396	232.5
40.00	7.50	998	2130.5	15.716	1.3029	.5439	378	.00027	2.945	271.1	5.295	1.496	249.1
40.83	7.35	993	2127.9	15.716	1.3033	.5433	377	.00026	2.957	271.4	5.369	1.498	249.5
80.00	3.75	847	2049.8	15.716	1.3171	.5252	337	.00023	3.354	280.5	8.519	1.578	262.8
100.00	3.00	803	2026.5	15.716	1.3215	.5198	324	.00022	3.491	283.2	9.944	1.601	266.6
200.00	1.50	676	1961.8	15.716	1.3341	.5049	286	.00019	3.932	290.4	16.132	1.663	277.0
300.00	1.00	611	1928.9	15.716	1.3404	.4979	265	.00017	4.204	294.0	21.449	1.694	282.1
500.00	.60	536	1891.9	15.716	1.3476	.4902	239	.00016	4.566	298.0	30.751	1.728	287.8
800.00	.37	474	1861.9	15.716	1.3531	.4846	217	.00014	4.919	301.2	42.881	1.755	292.2
1000.00	.30	447	1848.9	15.716	1.3552	.4824	207	.00013	5.094	302.5	50.232	1.767	294.2
1500.00	.20	402	1827.2	15.716	1.3589	.4788	190	.00012	5.424	304.8	66.995	1.786	297.4
R = 0.70, PERCENT FUEL = 50.34, O/F = 0.986													
1.00	300.00	2494	2644.0	16.862	1.2004	0.7547	709	0.00064					
1.05	285.71	2474	2629.8	16.866	1.2017	.7474	705	.00063	0.286	395.0	2.172	0.203	35.3
1.60	187.50	2305	2511.3	16.891	1.2130	.6937	673	.00057	.898	217.2	1.010	.618	107.5
1.78	168.33	2262	2482.3	16.895	1.2157	.6824	665	.00055	1.000	216.2	1.000	.682	118.6
2.00	150.00	2216	2451.9	16.899	1.2186	.6714	656	.00054	1.100	217.0	1.009	.743	129.3
10.00	30.00	1633	2089.7	16.916	1.2497	.5884	536	.00039	2.151	257.6	2.185	1.263	219.6
20.00	15.00	1418	1965.6	16.916	1.2618	.5662	487	.00035	2.541	272.8	3.431	1.397	243.0
20.41	14.70	1412	1962.2	16.916	1.2622	.5656	486	.00035	2.552	273.2	3.478	1.401	243.6
40.00	7.50	1225	1858.1	16.916	1.2749	.5447	440	.00030	2.927	285.4	5.506	1.504	261.5
40.83	7.35	1219	1855.2	16.916	1.2753	.5441	439	.00030	2.939	285.8	5.585	1.507	262.0
80.00	3.75	1052	1765.6	16.916	1.2892	.5236	396	.00027	3.321	295.9	8.943	1.590	276.5
100.00	3.00	1000	1738.7	16.916	1.2939	.5172	382	.00025	3.452	298.9	10.470	1.614	280.7
200.00	1.50	852	1663.4	16.916	1.3082	.4986	341	.00022	3.871	307.0	17.139	1.680	292.1
300.00	1.00	773	1624.8	16.916	1.3163	.4889	318	.00020	4.129	311.1	22.897	1.713	297.8
500.00	.60	683	1581.1	16.916	1.3257	.4781	290	.00018	4.470	315.6	33.006	1.749	304.1
800.00	.37	608	1545.5	16.916	1.3334	.4698	265	.00016	4.803	319.2	46.234	1.778	309.2
1000.00	.30	575	1530.0	16.916	1.3369	.4662	254	.00016	4.968	320.8	54.262	1.790	311.3
1500.00	.20	519	1504.0	16.916	1.3426	.4604	235	.00014	5.280	323.4	72.597	1.811	315.0

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TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 1500

FOR LIQUID AMMONIA WITH LIQUID OXYGEN

(a) Continued. Combustion-chamber pressure, 300 pounds per square inch absolute; equilibrium composition during isentropic expansion

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Molecular weight, $\mathcal{M}$	Isentropic exponent, γ	Specific heat, c_p, $\frac{cal}{(g)(^{\circ}K)}$	Absolute viscosity, μ, micropoises	Thermal conductivity, k, cal/(sec)(cm)(°K)	Mach number, M	Specific impulse, I_{vac}, $\frac{(lb)(sec)}{lb}$	Area ratio, ε	Thrust coefficient, C_F	Specific impulse, I, $\frac{(lb)(sec)}{lb}$
R = 0.80, PERCENT FUEL = 47.01, O/F = 1.127													
1.00	300.00	2734	2471.0	17.915	1.1669	0.9466	762	0.00083					
1.05	285.71	2717	2456.3	17.924	1.1679	.9345	759	.00081	0.290	401.6	2.151	0.201	35.8
1.60	187.50	2563	2333.2	17.996	1.1777	.8356	730	.00071	.909	222.0	1.008	.613	109.5
1.76	170.41	2528	2306.4	18.009	1.1802	.8150	723	.00069	1.000	221.1	1.000	.670	119.7
2.00	150.00	2482	2271.1	18.026	1.1837	.7886	714	.00066	1.111	222.1	1.011	.739	131.9
10.00	30.00	1893	1884.7	18.112	1.2269	.5974	597	.00044	2.145	265.9	2.241	1.265	225.9
20.00	15.00	1661	1749.8	18.115	1.2396	.5683	547	.00039	2.528	282.2	3.544	1.403	250.5
20.41	14.70	1654	1746.0	18.115	1.2399	.5676	546	.00038	2.539	282.6	3.594	1.407	251.2
40.00	7.50	1449	1631.7	18.116	1.2514	.5461	499	.00034	2.906	295.8	5.731	1.514	270.2
40.83	7.35	1443	1628.4	18.116	1.2518	.5455	497	.00034	2.917	296.2	5.815	1.517	270.8
80.00	3.75	1257	1529.0	18.116	1.2640	.5251	452	.00030	3.288	307.3	9.387	1.604	286.3
100.00	3.00	1199	1498.9	18.116	1.2684	.5184	438	.00029	3.414	310.5	11.022	1.629	290.8
200.00	1.50	1033	1414.2	18.116	1.2826	.4979	394	.00025	3.815	319.5	18.203	1.699	303.2
300.00	1.00	943	1370.3	18.116	1.2909	.4867	370	.00023	4.060	324.0	24.443	1.734	309.5
500.00	.60	839	1320.4	18.116	1.3015	.4735	340	.00021	4.382	329.1	35.455	1.772	316.4
800.00	.37	752	1279.4	18.116	1.3109	.4625	314	.00019	4.695	333.2	49.927	1.804	322.0
1000.00	.30	713	1261.5	18.116	1.3151	.4578	301	.00018	4.850	334.9	58.736	1.817	324.4
1500.00	.20	646	1231.3	18.116	1.3223	.4500	284	.00017	5.143	337.8	78.899	1.840	328.4
R = 0.90, PERCENT FUEL = 44.09, O/F = 1.268													
1.00	300.00	2877	2319.5	18.816	1.1439	1.2266	798	0.00108					
1.05	285.71	2862	2304.7	18.831	1.1443	1.2148	795	.00107	0.292	402.3	2.134	0.199	35.9
1.60	187.50	2731	2180.9	18.956	1.1481	1.1072	770	.00095	.919	223.2	1.006	.609	109.8
1.74	172.33	2704	2156.8	18.979	1.1491	1.0847	765	.00093	1.000	222.5	1.000	.660	119.0
2.00	150.00	2661	2117.9	19.015	1.1510	1.0470	757	.00089	1.122	223.8	1.013	.735	132.5
10.00	30.00	2135	1717.1	19.278	1.1950	.6645	653	.00052	2.140	270.8	2.320	1.270	229.0
20.00	15.00	1900	1573.1	19.307	1.2156	.5881	604	.00043	2.506	288.2	3.704	1.414	254.8
20.41	14.70	1893	1569.1	19.308	1.2161	.5866	602	.00043	2.517	288.7	3.757	1.418	255.5
40.00	7.50	1675	1445.7	19.315	1.2303	.5510	555	.00038	2.871	302.9	6.033	1.530	275.7
40.83	7.35	1668	1442.2	19.315	1.2306	.5502	554	.00038	2.882	303.3	6.122	1.533	276.3
80.00	3.75	1467	1333.8	19.316	1.2422	.5277	507	.00033	3.243	315.3	9.951	1.625	292.9
100.00	3.00	1404	1300.9	19.316	1.2461	.5209	492	.00032	3.364	318.8	11.711	1.652	297.7
200.00	1.50	1221	1207.4	19.316	1.2587	.5006	447	.00028	3.751	328.6	19.495	1.726	311.1
300.00	1.00	1122	1158.5	19.316	1.2666	.4887	421	.00026	3.985	333.6	26.305	1.763	317.8
500.00	.60	1006	1102.6	19.316	1.2771	.4741	390	.00024	4.291	339.2	38.394	1.805	325.4
800.00	.37	907	1056.4	19.316	1.2868	.4616	362	.00021	4.586	343.8	54.374	1.839	331.5
1000.00	.30	863	1036.1	19.316	1.2914	.4559	349	.00020	4.731	345.7	64.136	1.854	334.2
1500.00	.20	787	1001.7	19.316	1.2997	.4461	338	.00019	5.005	349.0	86.552	1.879	338.6
R = 0.95, PERCENT FUEL = 42.76, O/F = 1.339													
1.00	300.00	2913	2250.6	19.201	1.1381	1.3349	810	0.00119					
1.05	285.71	2899	2235.9	19.218	1.1382	1.3256	807	.00117	0.293	400.7	2.130	0.199	35.7
1.60	187.50	2774	2112.9	19.361	1.1395	1.2397	783	.00107	.921	222.6	1.006	.608	109.5
1.73	172.91	2751	2089.9	19.387	1.1399	1.2220	778	.00105	1.000	222.0	1.000	.657	118.2
2.00	150.00	2709	2050.2	19.432	1.1408	1.1901	770	.00102	1.126	223.3	1.014	.734	132.1
10.00	30.00	2234	1647.3	19.815	1.1704	.7776	676	.00061	2.145	271.7	2.364	1.273	229.1
20.00	15.00	2015	1499.8	19.885	1.1957	.6375	631	.00048	2.498	289.9	3.808	1.420	255.6
20.41	14.70	2008	1495.7	19.887	1.1964	.6345	629	.00048	2.508	290.4	3.863	1.424	256.3
40.00	7.50	1791	1368.1	19.910	1.2173	.5646	583	.00040	2.848	305.2	6.237	1.540	277.1
40.83	7.35	1784	1364.5	19.910	1.2178	.5633	582	.00040	2.859	305.6	6.330	1.543	277.7
80.00	3.75	1577	1251.7	19.915	1.2316	.5315	535	.00035	3.210	318.0	10.324	1.638	294.8
100.00	3.00	1512	1217.3	19.916	1.2355	.5238	520	.00034	3.330	321.7	12.164	1.666	299.8
200.00	1.50	1321	1119.5	19.916	1.2477	.5026	474	.00030	3.709	332.0	20.318	1.743	313.7
300.00	1.00	1218	1068.1	19.916	1.2551	.4910	448	.00028	3.938	337.3	27.476	1.782	320.8
500.00	.60	1096	1009.2	19.916	1.2651	.4762	416	.00025	4.236	343.1	40.222	1.826	328.7
800.00	.37	992	960.2	19.916	1.2747	.4630	387	.00023	4.523	347.9	57.122	1.862	335.1
1000.00	.30	945	938.7	19.916	1.2792	.4571	374	.00022	4.664	350.0	67.468	1.877	337.9
1500.00	.20	864	902.1	19.916	1.2877	.4466	368	.00021	4.929	353.5	91.270	1.903	342.5

TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 1500 FOR LIQUID AMMONIA WITH LIQUID OXYGEN

(a) Continued. Combustion-chamber pressure, 300 pounds per square inch absolute; equilibrium composition during isentropic expansion

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Molecular weight, $\mathscr{M}$	Isentropic exponent, γ	Specific heat, c_p, $\frac{\text{cal}}{(\text{g})(^\circ\text{K})}$	Absolute viscosity, μ, micropoises	Thermal conductivity, k, cal/(sec)(cm)(°K)	Mach number, M	Specific impulse, I_{vac}, $\frac{(\text{lb})(\text{sec})}{\text{lb}}$	Area ratio, ε	Thrust coefficient, C_F	Specific impulse, I, $\frac{(\text{lb})(\text{sec})}{\text{lb}}$
R = 1.00, PERCENT FUEL = 41.51, O/F = 1.409													
1.00	300.00	2928	2185.7	19.542	1.1360	1.3651	817	0.00122					
1.05	285.71	2914	2171.2	19.560	1.1360	1.3572	814	.00121	0.294	398.3	2.128	0.198	33.5
1.60	187.50	2792	2049.6	19.711	1.1365	1.2845	791	.00112	.922	221.3	1.006	.608	108.8
1.73	173.12	2769	2027.3	19.738	1.1347	1.2700	786	.00110	1.000	220.7	1.000	.656	117.4
2.00	150.00	2728	1987.7	19.787	1.1371	1.2432	778	.00107	1.128	222.1	1.015	.733	131.3
10.00	30.00	2283	1587.6	20.239	1.1520	.9129	689	.00071	2.153	270.9	2.388	1.275	228.1
20.00	15.00	2089	1439.3	20.368	1.1665	.7746	649	.00058	2.508	289.6	3.887	1.424	254.9
20.41	14.70	2083	1438.1	20.371	1.1670	.7708	648	.00058	2.516	290.2	3.945	1.428	255.6
40.00	7.50	1891	1305.0	20.451	1.1861	.6592	607	.00047	2.843	305.7	6.453	1.547	276.8
40.83	7.35	1885	1301.2	20.453	1.1868	.6562	606	.00047	2.853	306.1	6.551	1.550	277.4
80.00	3.75	1691	1184.5	20.494	1.2080	.5771	563	.00039	3.180	319.3	10.799	1.649	295.2
100.00	3.00	1627	1148.7	20.502	1.2145	.5580	549	.00037	3.291	323.2	12.756	1.678	300.4
200.00	1.50	1434	1046.0	20.513	1.2327	.5153	503	.00032	3.649	334.1	21.438	1.759	314.9
300.00	1.00	1326	991.8	20.515	1.2418	.4983	477	.00030	3.869	339.7	29.067	1.801	322.3
500.00	.60	1199	929.3	20.516	1.2523	.4810	445	.00027	4.157	345.9	42.681	1.847	330.6
800.00	.37	1089	877.3	20.516	1.2619	.4668	415	.00024	4.434	351.0	60.786	1.885	337.4
1000.00	.30	1039	854.3	20.516	1.2664	.4604	402	.00023	4.570	353.2	71.892	1.902	340.4
1500.00	.20	953	815.2	20.516	1.2747	.4494	402	.00023	4.825	357.0	97.495	1.929	345.3
R = 1.10, PERCENT FUEL = 39.22, O/F = 1.550													
1.00	300.00	2913	2066.7	20.113	1.1386	1.2483	823	0.00113					
1.05	285.71	2898	2052.7	20.131	1.1387	1.2393	820	.00112	0.293	391.5	2.130	0.199	34.9
1.60	187.50	2779	1935.3	20.275	1.1402	1.1574	795	.00102	.921	217.5	1.006	.608	107.0
1.74	172.87	2749	1913.3	20.302	1.1406	1.1409	791	.00100	1.000	216.8	1.000	.657	115.5
2.00	150.00	2707	1875.4	20.347	1.1415	1.1117	782	.00097	1.126	218.2	1.014	.734	129.0
10.00	30.00	2236	1490.9	20.739	1.1633	.7848	686	.00062	2.150	265.5	2.368	1.273	223.8
20.00	15.00	2030	1349.6	20.834	1.1794	.6769	643	.00051	2.506	283.5	3.836	1.421	249.8
20.41	14.70	2023	1345.6	20.836	1.1800	.6741	642	.00051	2.517	284.0	3.892	1.425	250.5
40.00	7.50	1823	1222.4	20.889	1.1979	.5972	598	.00043	2.851	298.9	6.334	1.542	271.0
40.83	7.35	1817	1218.9	20.890	1.1984	.5952	597	.00043	2.861	299.3	6.430	1.545	271.6
80.00	3.75	1621	1109.0	20.916	1.2162	.5421	552	.00036	3.198	311.9	10.560	1.642	288.7
100.00	3.00	1557	1075.3	20.921	1.2219	.5284	537	.00035	3.312	315.6	12.464	1.671	293.7
200.00	1.50	1368	979.1	20.928	1.2385	.4945	492	.00030	3.677	326.0	20.903	1.750	307.6
300.00	1.00	1264	928.5	20.930	1.2474	.4794	466	.00028	3.900	331.3	28.314	1.790	314.7
500.00	.60	1140	870.2	20.931	1.2582	.4628	433	.00025	4.191	337.3	41.518	1.835	322.7
800.00	.37	1034	821.7	20.931	1.2681	.4491	404	.00023	4.472	342.1	59.048	1.872	329.1
1000.00	.30	986	800.3	20.931	1.2727	.4431	391	.00022	4.611	344.2	69.789	1.888	332.0
1500.00	.20	903	764.0	20.931	1.2811	.4327	388	.00021	4.871	347.8	94.528	1.915	336.7
R = 1.20, PERCENT FUEL = 37.16, O/F = 1.691													
1.00	300.00	2871	1960.2	20.593	1.1425	1.1178	822	0.00102					
1.05	285.71	2856	1946.7	20.609	1.1427	1.1093	819	.00101	0.293	384.1	2.133	0.199	34.2
1.60	187.50	2726	1833.7	20.742	1.1448	1.0346	793	.00092	.920	213.2	1.006	.609	104.9
1.74	172.57	2701	1812.2	20.767	1.1454	1.0197	788	.00090	1.000	212.6	1.000	.659	113.5
2.00	150.00	2659	1776.2	20.807	1.1464	.9945	780	.00087	1.124	213.8	1.014	.734	126.5
10.00	30.00	2173	1408.1	21.154	1.1691	.7271	679	.00057	2.150	259.7	2.355	1.272	219.2
20.00	15.00	1968	1273.5	21.235	1.1851	.6378	635	.00048	2.509	277.2	3.805	1.419	244.4
20.41	14.70	1962	1269.7	21.237	1.1856	.6355	633	.00048	2.519	277.7	3.861	1.423	245.1
40.00	7.50	1762	1152.7	21.283	1.2035	.5686	589	.00040	2.856	292.1	6.270	1.539	265.1
40.83	7.35	1756	1149.3	21.284	1.2041	.5669	588	.00040	2.866	292.5	6.364	1.542	265.6
80.00	3.75	1562	1045.3	21.305	1.2220	.5192	543	.00035	3.206	304.6	10.432	1.638	282.2
100.00	3.00	1499	1013.4	21.309	1.2278	.5067	528	.00033	3.321	308.2	12.304	1.666	287.0
200.00	1.50	1314	922.6	21.315	1.2443	.4759	482	.00029	3.690	318.2	20.590	1.744	300.5
300.00	1.00	1212	874.9	21.316	1.2531	.4620	456	.00026	3.916	323.3	27.856	1.784	307.3
500.00	.60	1091	820.1	21.317	1.2640	.4465	424	.00024	4.211	329.0	40.785	1.829	315.0
800.00	.37	988	774.6	21.317	1.2738	.4338	395	.00022	4.497	333.7	57.925	1.865	321.2
1000.00	.30	941	754.5	21.317	1.2783	.4281	382	.00021	4.637	335.7	68.417	1.880	323.9
1500.00	.20	861	720.5	21.317	1.2867	.4183	376	.00020	4.900	339.1	92.559	1.907	328.4
R = 1.50, PERCENT FUEL = 32.12, O/F = 2.114													
1.00	300.00	2728	1698.4	21.784	1.1504	0.9074	809	0.00083					
1.05	285.71	2712	1686.3	21.797	1.1507	.9009	806	.00082	0.292	364.0	2.138	0.199	32.5
1.60	187.50	2579	1585.0	21.908	1.1540	.8450	779	.00075	.917	201.8	1.007	.610	99.3
1.74	172.00	2551	1564.9	21.929	1.1548	.8335	773	.00073	1.000	201.1	1.000	.662	107.8
2.00	150.00	2509	1533.6	21.962	1.1562	.8152	764	.00071	1.121	202.2	1.013	.736	119.8
10.00	30.00	2013	1206.6	22.230	1.1845	.6144	658	.00048	2.148	244.7	2.325	1.271	206.9
20.00	15.00	1804	1088.6	22.286	1.2028	.5472	611	.00040	2.511	260.7	3.732	1.415	230.4
20.41	14.70	1798	1085.3	22.287	1.2033	.5455	609	.00040	2.521	261.2	3.786	1.419	231.0
40.00	7.50	1600	983.5	22.314	1.2219	.4971	563	.00034	2.866	274.3	6.106	1.532	249.4
40.83	7.35	1594	980.6	22.314	1.2225	.4959	562	.00034	2.877	274.6	6.197	1.535	249.9
80.00	3.75	1405	890.8	22.325	1.2400	.4620	515	.00030	3.227	285.6	10.088	1.628	265.1
100.00	3.00	1345	863.5	22.327	1.2453	.4532	500	.00028	3.346	288.9	11.874	1.656	269.5
200.00	1.50	1170	786.0	22.329	1.2604	.4310	455	.00025	3.729	297.8	19.750	1.731	281.8
300.00	1.00	1075	745.5	22.329	1.2690	.4199	429	.00023	3.963	302.4	26.630	1.769	288.0
500.00	.60	963	699.2	22.329	1.2794	.4075	397	.00021	4.270	307.5	38.831	1.811	294.9
800.00	.37	868	661.0	22.329	1.2890	.3969	368	.00019	4.566	311.6	54.950	1.846	300.5
1000.00	.30	825	644.2	22.329	1.2936	.3922	355	.00018	4.711	313.4	64.794	1.860	302.9
1500.00	.20	752	615.7	22.329	1.3017	.3840	345	.00017	4.986	316.4	87.389	1.885	306.9

TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 1500 FOR LIQUID AMMONIA WITH LIQUID OXYGEN

(a) Concluded. Combustion-chamber pressure, 300 pounds per square inch absolute; equilibrium composition during isentropic expansion

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Molecular weight, $\mathscr{M}$	Isentropic exponent, γ	Specific heat, c_p, $\frac{cal}{(g)(^{\circ}K)}$	Absolute viscosity, μ, micropoises	Thermal conductivity, k, cal/(sec)(cm)(°K)	Mach number, M	Specific impulse, I_{vac}, $\frac{(lb)(sec)}{lb}$	Area ratio, ε	Thrust coefficient, C_F	Specific impulse, I, $\frac{(lb)(sec)}{lb}$
R = 2.00, PERCENT FUEL = 26.19, O/F = 2.818													
1.00	300.00	2515	1391.0	23.307	1.1630	0.7201	783	0.00065					
1.05	285.71	2499	1380.5	23.318	1.1635	.7148	779	.00064	0.290	337.8	2.147	0.200	30.1
1.60	187.50	2362	1293.5	23.403	1.1694	.6684	750	.00058	.912	186.8	1.008	.612	92.1
1.75	171.00	2332	1275.1	23.419	1.1709	.6584	744	.00057	1.000	186.2	1.000	.667	100.4
2.00	150.00	2290	1249.4	23.442	1.1731	.6441	734	.00055	1.115	187.1	1.012	.738	111.0
10.00	30.00	1782	973.0	23.611	1.2117	.4949	620	.00037	2.145	224.9	2.275	1.268	190.7
20.00	15.00	1574	875.2	23.636	1.2308	.4530	570	.00032	2.517	239.0	3.612	1.408	211.8
20.41	14.70	1568	872.5	23.636	1.2314	.4520	569	.00032	2.528	239.4	3.663	1.412	212.4
40.00	7.50	1377	789.3	23.645	1.2484	.4238	521	.00028	2.686	250.8	5.849	1.521	228.8
40.83	7.35	1371	787.0	23.645	1.2488	.4230	520	.00027	2.897	251.1	5.934	1.524	229.3
80.00	3.75	1195	714.5	23.647	1.2634	.4033	473	.00024	3.265	260.6	9.579	1.613	242.6
100.00	3.00	1141	692.6	23.648	1.2680	.3977	458	.00023	3.390	263.4	11.245	1.639	246.5
200.00	1.50	982	630.9	23.648	1.2820	.3821	414	.00020	3.790	271.1	18.564	1.709	257.2
300.00	1.00	898	598.8	23.648	1.2900	.3738	388	.00019	4.035	275.0	24.925	1.745	262.5
500.00	.60	799	562.5	23.648	1.3003	.3639	357	.00017	4.357	279.4	36.156	1.785	268.5
800.00	.37	716	532.6	23.648	1.3095	.3556	330	.00015	4.668	282.9	50.923	1.817	273.3
1000.00	.30	679	519.5	23.648	1.3138	.3519	317	.00015	4.822	284.4	59.913	1.830	275.4
1500.00	.20	616	497.5	23.648	1.3214	.3455	302	.00014	5.113	286.9	80.490	1.853	278.8
R = 3.00, PERCENT FUEL = 19.13, O/F = 4.227													
1.00	300.00	2163	1024.7	25.320	1.1942	0.5151	727	0.00045					
1.05	285.71	2146	1016.4	25.326	1.1953	.5112	723	.00044	0.286	300.3	2.168	0.202	26.8
1.60	187.50	2004	947.9	25.367	1.2055	.4795	690	.00040	.901	165.3	1.009	.617	81.7
1.78	168.77	1969	931.6	25.376	1.2083	.4721	682	.00039	1.000	164.5	1.000	.680	90.0
2.00	150.00	1929	913.6	25.384	1.2114	.4641	673	.00038	1.102	165.2	1.009	.742	98.3
10.00	30.00	1427	703.2	25.434	1.2533	.3878	550	.00027	2.146	196.3	2.189	1.263	167.3
20.00	15.00	1236	631.1	25.437	1.2679	.3700	499	.00023	2.535	207.8	3.429	1.397	185.1
20.41	14.70	1231	629.2	25.437	1.2683	.3696	498	.00023	2.547	208.1	3.476	1.401	185.5
40.00	7.50	1065	568.9	25.438	1.2814	.3558	452	.00020	2.925	217.3	5.488	1.504	199.1
40.83	7.35	1060	567.2	25.438	1.2818	.3554	450	.00020	2.936	217.6	5.566	1.506	199.5
80.00	3.75	912	515.5	25.438	1.2944	.3434	406	.00018	3.323	225.2	8.893	1.589	210.5
100.00	3.00	866	500.0	25.438	1.2988	.3396	392	.00017	3.455	227.5	10.406	1.613	213.7
200.00	1.50	737	456.7	25.438	1.3123	.3282	350	.00015	3.878	233.6	17.008	1.679	222.3
300.00	1.00	668	434.4	25.438	1.3202	.3221	326	.00014	4.139	236.6	22.703	1.711	226.6
500.00	.60	590	409.4	25.438	1.3300	.3148	297	.00012	4.482	240.0	32.694	1.747	231.4
800.00	.37	524	388.9	25.438	1.3385	.3089	272	.00011	4.817	242.8	45.747	1.776	235.2
1000.00	.30	495	380.1	25.438	1.3423	.3063	261	.00011	4.983	243.9	53.660	1.788	236.8
1500.00	.20	446	365.2	25.438	1.3491	.3019	242	.00010	5.296	245.9	71.702	1.809	239.6
R = 4.00, PERCENT FUEL = 15.07, O/F = 5.636													
1.00	300.00	1875	814.0	26.561	1.2253	0.4158	672	0.00034					
1.05	285.71	1858	807.1	26.563	1.2266	.4133	668	.00034	0.283	272.7	2.187	0.204	24.3
1.60	187.50	1717	750.8	26.579	1.2377	.3939	633	.00031	.891	149.5	1.011	.621	74.1
1.80	166.91	1680	736.1	26.582	1.2406	.3893	624	.00030	1.000	148.7	1.000	.690	82.3
2.00	150.00	1645	722.8	26.584	1.2433	.3853	616	.00029	1.092	149.1	1.007	.747	89.1
10.00	30.00	1179	554.0	26.595	1.2773	.3442	493	.00022	2.149	175.9	2.137	1.261	150.4
20.00	15.00	1012	497.3	26.596	1.2901	.3322	445	.00019	2.548	185.8	3.323	1.392	166.0
20.41	14.70	1007	495.8	26.596	1.2905	.3319	444	.00019	2.560	186.1	3.368	1.395	166.4
40.00	7.50	864	448.9	26.596	1.3028	.3215	399	.00017	2.947	194.0	5.282	1.494	178.2
40.83	7.35	859	447.5	26.596	1.3032	.3211	398	.00016	2.959	194.2	5.356	1.497	178.6
80.00	3.75	733	407.6	26.596	1.3163	.3110	356	.00014	3.358	200.7	8.500	1.577	188.0
100.00	3.00	695	395.7	26.596	1.3205	.3078	343	.00014	3.494	202.6	9.924	1.600	190.8
200.00	1.50	585	362.6	26.596	1.3341	.2983	303	.00012	3.933	207.8	16.104	1.662	198.2
300.00	1.00	528	345.8	26.596	1.3416	.2934	281	.00011	4.204	210.4	21.408	1.692	201.8
500.00	.60	463	326.9	26.596	1.3509	.2877	254	.00010	4.564	213.2	30.675	1.726	205.9
800.00	.37	410	311.5	26.596	1.3580	.2834	231	.00009	4.916	215.5	42.731	1.753	209.1
1000.00	.30	386	304.9	26.596	1.3608	.2818	221	.00008	5.091	216.4	50.025	1.765	210.5
1500.00	.20	347	293.8	26.596	1.3650	.2794	203	.00008	5.424	218.0	66.635	1.784	212.7
R = 5.00, PERCENT FUEL = 12.43, O/F = 7.046													
1.00	300.00	1640	677.0	27.397	1.2496	0.3655	621	0.00028					
1.05	285.71	1624	671.3	27.398	1.2507	.3640	617	.00028	0.280	251.0	2.200	0.205	22.4
1.60	187.50	1491	623.7	27.403	1.2601	.3523	583	.00026	.885	137.2	1.013	.624	68.1
1.81	168.69	1453	610.5	27.404	1.2628	.3493	573	.00025	1.000	136.4	1.000	.697	76.1
2.00	150.00	1424	600.1	27.404	1.2648	.3470	565	.00025	1.085	136.7	1.006	.750	81.8
10.00	30.00	1002	459.7	27.406	1.2941	.3191	448	.00018	2.151	160.5	2.106	1.260	137.5
20.00	15.00	853	413.2	27.406	1.3064	.3091	402	.00016	2.555	169.3	3.257	1.389	151.5
20.41	14.70	849	411.9	27.406	1.3068	.3088	400	.00016	2.567	169.5	3.301	1.392	151.9
40.00	7.50	723	373.6	27.406	1.3198	.2993	358	.00014	2.961	176.5	5.149	1.489	162.5
40.83	7.35	720	372.6	27.406	1.3201	.2990	357	.00014	2.973	176.7	5.221	1.492	162.8
80.00	3.75	610	340.2	27.406	1.3335	.2899	317	.00012	3.380	182.4	8.241	1.569	171.2
100.00	3.00	577	330.6	27.406	1.3378	.2871	305	.00012	3.519	184.1	9.603	1.591	173.6
200.00	1.50	483	304.0	27.406	1.3509	.2792	267	.00010	3.972	188.6	15.499	1.651	180.2
300.00	1.00	434	290.5	27.406	1.3579	.2751	247	.00009	4.252	190.9	20.540	1.681	183.4
500.00	.60	379	275.5	27.406	1.3649	.2712	222	.00008	4.626	193.3	29.326	1.713	186.9
800.00	.37	334	263.4	27.406	1.3697	.2687	201	.00007	4.993	195.3	40.744	1.739	189.7
1000.00	.30	315	258.1	27.406	1.3715	.2677	191	.00007	5.175	196.1	47.646	1.750	190.9
1500.00	.20	282	249.4	27.406	1.3740	.2664	175	.00006	5.520	197.5	63.359	1.768	192.9

TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 1500 FOR LIQUID AMMONIA WITH LIQUID OXYGEN

(b) Combustion-chamber pressure, 300 pounds per square inch absolute; frozen composition during isentropic expansion

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Molecular weight, $\mathcal{M}$	Isentropic exponent, γ	Specific heat, c_p, $\frac{cal}{(g)(^{\circ}K)}$	Absolute viscosity, μ, micropoises	Thermal conductivity, k, $\frac{cal/(sec)}{(cm)(^{\circ}K)}$	Mach number, M	Specific impulse, I_{vac}, $\frac{(lb)(sec)}{lb}$	Area ratio, ε	Thrust coefficient, C_F	Specific impulse, I, $\frac{(lb)(sec)}{lb}$
R = 0.40, PERCENT FUEL = 63.95, O/F = 0.564													
1.00	300.00	1949	3350.2	13.316	1.2956	0.6540	453	0.00038					
1.05	285.71	1934	3340.4	13.316	1.2966	.6524	450	.00038	0.275	326.2	2.226	0.208	29.1
1.60	187.50	1210	3260.5	13.316	1.3059	.6381	421	.00035	.872	177.3	1.015	.630	88.3
1.84	163.20	1171	3235.9	13.316	1.3082	.6335	412	.00034	1.000	176.0	1.000	.712	99.7
2.00	150.00	1148	3221.3	13.316	1.3100	.6307	406	.00033	1.072	176.3	1.004	.756	105.9
10.00	30.00	772	2993.1	13.316	1.3421	.5855	309	.00024	2.149	204.7	2.030	1.258	176.3
20.00	15.00	646	2919.9	13.316	1.3530	.5720	272	.00021	2.569	215.2	3.093	1.381	193.5
20.41	14.70	643	2917.9	13.316	1.3532	.5717	271	.00021	2.581	215.4	3.133	1.384	193.9
40.00	7.50	538	2858.8	13.316	1.3618	.5617	237	.00018	2.998	223.7	4.825	1.476	206.8
40.83	7.35	535	2857.1	13.316	1.3620	.5615	236	.00018	3.011	223.9	4.888	1.478	207.1
80.00	3.75	447	2807.9	13.316	1.3680	.5548	206	.00015	3.447	230.6	7.629	1.550	217.2
100.00	3.00	421	2793.5	13.316	1.3696	.5530	196	.00015	3.597	232.5	8.863	1.571	220.1
200.00	1.50	349	2753.8	13.316	1.3744	.5478	168	.00012	4.083	237.7	14.191	1.626	227.8
300.00	1.00	312	2733.8	13.316	1.3768	.5453	154	.00011	4.383	240.3	18.744	1.655	231.6
500.00	.60	271	2711.6	13.316	1.3799	.5427	136	.00010	4.781	243.2	26.660	1.682	235.7
800.00	.37	238	2693.7	13.316	1.3842	.5377	122	.00009	5.163	245.5	36.978	1.705	239.0
1000.00	.30	224	2686.0	13.316	1.3871	.5348	115	.00008	5.351	246.4	43.187	1.715	240.4
1500.00	.20	200	2673.2	13.316	1.3927	.5293	104	.00007	5.707	248.0	57.266	1.732	242.7
R = 0.50, PERCENT FUEL = 58.67, O/F = 0.705													
1.00	300.00	1784	3075.9	14.516	1.2629	0.6588	555	0.00046					
1.05	285.71	1766	3064.0	14.516	1.2630	.6573	551	.00046	0.279	359.6	2.206	0.206	32.1
1.60	187.50	1617	2966.5	14.516	1.2697	.6444	520	.00042	.882	196.3	1.013	.626	97.5
1.82	165.20	1574	2938.9	14.516	1.2719	.6404	510	.00041	1.000	195.0	1.000	.700	109.2
2.00	150.00	1541	2918.3	14.516	1.2736	.6372	503	.00041	1.083	195.5	1.006	.751	117.1
10.00	30.00	1074	2632.5	14.516	1.3037	.5847	394	.00030	2.149	229.0	2.090	1.260	196.4
20.00	15.00	911	2538.5	14.516	1.3201	.5646	351	.00026	2.555	241.3	3.218	1.387	216.2
20.41	14.70	906	2535.9	14.516	1.3205	.5641	350	.00026	2.568	241.7	3.261	1.390	216.8
40.00	7.50	768	2459.0	14.516	1.3335	.5474	311	.00022	2.967	251.4	5.064	1.486	231.7
40.83	7.35	764	2456.9	14.516	1.3339	.5469	310	.00022	2.979	251.7	5.134	1.489	232.1
80.00	3.75	644	2392.2	14.516	1.3450	.5338	273	.00019	3.396	259.6	8.071	1.565	243.9
100.00	3.00	608	2373.0	14.516	1.3482	.5301	262	.00018	3.539	261.9	9.395	1.586	247.3
200.00	1.50	508	2320.2	14.516	1.3571	.5203	228	.00016	4.003	268.2	15.125	1.645	256.4
300.00	1.00	456	2293.5	14.516	1.3609	.5163	210	.00014	4.292	271.3	20.032	1.674	260.9
500.00	.60	398	2263.7	14.516	1.3650	.5120	188	.00013	4.673	274.8	28.600	1.705	265.8
800.00	.37	351	2239.6	14.516	1.3683	.5086	169	.00012	5.045	277.5	39.755	1.730	269.7
1000.00	.30	330	2229.2	14.516	1.3696	.5073	161	.00011	5.228	278.7	46.505	1.741	271.4
1500.00	.20	296	2211.9	14.516	1.3717	.5053	146	.00010	5.575	280.6	61.880	1.759	274.2
R = 0.60, PERCENT FUEL = 54.19, O/F = 0.845													
1.00	300.00	2169	2843.5	15.708	1.2400	0.6535	639	0.00052					
1.05	285.71	2149	2830.1	15.708	1.2406	.6523	635	.00051	0.281	381.4	2.193	0.205	34.0
1.60	187.50	1979	2720.2	15.708	1.2456	.6416	602	.00048	.889	208.7	1.012	.623	103.6
1.80	166.59	1933	2691.0	15.708	1.2472	.6383	593	.00047	1.000	207.6	1.000	.693	115.2
2.00	150.00	1893	2665.6	15.708	1.2486	.6354	585	.00046	1.091	208.2	1.007	.748	124.4
10.00	30.00	1357	2337.0	15.708	1.2750	.5865	468	.00035	2.151	245.5	2.139	1.262	209.9
20.00	15.00	1165	2226.6	15.708	1.2888	.5646	421	.00030	2.548	259.4	3.328	1.393	231.7
20.41	14.70	1160	2223.6	15.708	1.2892	.5639	420	.00030	2.560	259.7	3.373	1.396	232.2
40.00	7.50	994	2132.1	15.708	1.3034	.5455	377	.00026	2.946	270.8	5.291	1.496	248.8
40.83	7.35	990	2129.5	15.708	1.3038	.5429	376	.00026	2.958	271.1	5.365	1.499	249.2
80.00	3.75	844	2051.6	15.708	1.3175	.5249	336	.00023	3.356	280.2	8.510	1.578	262.5
100.00	3.00	799	2028.4	15.708	1.3219	.5194	323	.00022	3.492	282.8	9.934	1.601	266.3
200.00	1.50	674	1964.0	15.708	1.3345	.5048	285	.00019	3.933	290.0	16.114	1.663	276.6
300.00	1.00	608	1931.1	15.708	1.3408	.4977	264	.00017	4.206	293.6	21.423	1.694	281.8
500.00	.60	533	1894.3	15.708	1.3479	.4901	239	.00015	4.568	297.6	30.711	1.728	287.4
800.00	.37	472	1864.4	15.708	1.3534	.4845	216	.00014	4.922	300.8	42.823	1.755	291.9
1000.00	.30	445	1851.5	15.708	1.3555	.4823	206	.00013	5.097	302.1	50.162	1.766	293.8
1500.00	.20	400	1829.8	15.708	1.3590	.4789	189	.00012	5.428	304.4	66.899	1.784	297.0
R = 0.70, PERCENT FUEL = 50.34, O/F = 0.986													
1.00	300.00	2494	2644.0	16.862	1.2247	0.6424	709	0.00056					
1.05	285.71	2472	2629.8	16.862	1.2251	.6414	705	.00056	0.281	394.8	2.183	0.204	35.2
1.60	187.50	2286	2511.7	16.862	1.2291	.6321	670	.00052	.894	216.5	1.011	.620	107.3
1.79	167.56	2239	2481.7	16.862	1.2303	.6295	661	.00051	1.000	215.4	1.000	.687	118.8
2.00	150.00	2193	2452.8	16.862	1.2315	.6270	652	.00050	1.096	216.1	1.008	.746	129.0
10.00	30.00	1604	2095.0	16.862	1.2525	.5846	530	.00039	2.154	256.2	2.175	1.264	218.6
20.00	15.00	1391	1972.9	16.862	1.2645	.5635	481	.00034	2.545	271.2	3.418	1.397	241.7
20.41	14.70	1385	1969.5	16.862	1.2648	.5628	480	.00034	2.556	271.6	3.460	1.401	242.3
40.00	7.50	1200	1867.2	16.862	1.2777	.5422	435	.00030	2.932	283.7	5.473	1.503	260.0
40.83	7.35	1195	1864.3	16.862	1.2781	.5415	433	.00030	2.944	284.0	5.551	1.506	260.5
80.00	3.75	1029	1776.3	16.862	1.2922	.5212	390	.00026	3.328	294.0	8.882	1.589	274.8
100.00	3.00	978	1749.9	16.862	1.2968	.5149	377	.00025	3.459	296.9	10.396	1.613	278.9
200.00	1.50	852	1676.1	16.862	1.3111	.4967	336	.00022	3.880	304.9	17.002	1.678	290.2
300.00	1.00	755	1638.2	16.862	1.3191	.4872	313	.00020	4.140	308.9	22.701	1.711	295.8
500.00	.60	666	1595.5	16.862	1.3283	.4769	285	.00018	4.484	313.4	32.704	1.747	302.1
800.00	.37	593	1560.6	16.862	1.3358	.4688	261	.00016	4.819	316.9	45.786	1.775	307.0
1000.00	.30	560	1545.5	16.862	1.3391	.4653	249	.00015	4.985	318.5	53.725	1.788	309.2
1500.00	.20	505	1520.0	16.862	1.3446	.4598	230	.00014	5.299	321.0	71.849	1.808	312.7

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CQ-4 back

TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 1500

FOR LIQUID AMMONIA WITH LIQUID OXYGEN

(b) Continued. Combustion-chamber pressure, 300 pounds per square inch absolute; frozen composition during isentropic expansion

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Molecular weight, $\mathscr{M}$	Isentropic exponent, γ	Specific heat, c_p, $\frac{cal}{(g)(^{\circ}K)}$	Absolute viscosity, μ, micropoises	Thermal conductivity, k, cal/(sec)(cm)(°K)	Mach number, M	Specific impulse, I_{vac}, $\frac{(lb)(sec)}{lb}$	Area ratio, ϵ	Thrust coefficient, C_F	Specific impulse, I, $\frac{(lb)(sec)}{lb}$
R = 0.80, PERCENT FUEL = 47.01, O/F = 1.127													
1.00	300.00	2734	2471.0	17.915	1.2149	0.6272	762	0.00058					
1.05	285.71	2711	2456.3	17.915	1.2152	.6263	758	.00058	0.284	401.1	2.177	0.203	35.8
1.60	187.50	2515	2334.3	17.915	1.2185	.6186	722	.00055	.897	220.3	1.010	.619	109.1
1.78	168.19	2466	2304.3	17.915	1.2194	.6166	713	.00054	1.000	219.3	1.000	.684	120.5
2.00	150.00	2416	2273.3	17.915	1.2204	.6143	703	.00053	1.100	220.1	1.009	.744	131.2
10.00	30.00	1790	1900.0	17.915	1.2382	.5766	577	.00041	2.155	261.7	2.200	1.265	222.9
20.00	15.00	1564	1771.2	17.915	1.2482	.5578	527	.00037	2.543	277.3	3.471	1.400	246.8
20.41	14.70	1557	1767.7	17.915	1.2486	.5572	525	.00037	2.554	277.8	3.519	1.404	247.4
40.00	7.50	1359	1659.0	17.915	1.2602	.5373	479	.00032	2.924	290.5	5.599	1.508	265.8
40.83	7.35	1353	1655.9	17.915	1.2606	.5367	477	.00032	2.936	290.8	5.680	1.511	266.3
80.00	3.75	1174	1561.8	17.915	1.2734	.5166	433	.00028	3.311	301.4	9.146	1.596	281.3
100.00	3.00	1119	1533.4	17.915	1.2780	.5100	419	.00027	3.438	304.5	10.728	1.621	285.6
200.00	1.50	959	1453.6	17.915	1.2924	.4903	375	.00024	3.846	313.1	17.662	1.689	297.5
300.00	1.00	874	1412.4	17.915	1.3009	.4796	351	.00022	4.096	317.4	23.671	1.722	303.5
500.00	.60	776	1365.7	17.915	1.3112	.4673	322	.00020	4.426	322.2	34.253	1.760	310.1
800.00	.37	693	1327.4	17.915	1.3201	.4574	296	.00018	4.747	326.1	48.133	1.790	315.5
1000.00	.30	656	1310.7	17.915	1.3241	.4532	284	.00017	4.906	327.7	56.572	1.803	317.7
1500.00	.20	594	1282.6	17.915	1.3308	.4463	263	.00015	5.207	330.5	75.868	1.825	321.6
R = 0.90, PERCENT FUEL = 44.09, O/F = 1.268													
1.00	300.00	2877	2319.5	18.816	1.2093	0.6102	798	0.00059					
1.05	285.71	2853	2304.8	18.816	1.2096	.6094	794	.00059	0.285	401.6	2.174	0.203	35.8
1.60	187.50	2651	2182.4	18.816	1.2127	.6023	757	.00056	.899	220.8	1.010	.618	109.2
1.78	168.54	2602	2152.8	18.816	1.2134	.6004	747	.00055	1.000	219.7	1.000	.682	120.4
2.00	150.00	2549	2121.1	18.816	1.2143	.5984	737	.00054	1.102	220.5	1.009	.744	131.4
10.00	30.00	1904	1744.8	18.816	1.2301	.5645	608	.00042	2.156	262.7	2.214	1.266	223.6
20.00	15.00	1669	1614.2	18.816	1.2393	.5469	557	.00038	2.541	278.7	3.503	1.402	247.7
20.41	14.70	1662	1610.6	18.816	1.2396	.5464	556	.00038	2.553	279.1	3.553	1.406	248.4
40.00	7.50	1456	1499.9	18.816	1.2502	.5278	508	.00034	2.920	292.1	5.672	1.511	267.0
40.83	7.35	1450	1496.8	18.816	1.2505	.5272	507	.00033	2.931	292.5	5.755	1.514	267.6
80.00	3.75	1264	1400.5	18.816	1.2626	.5079	461	.00030	3.302	303.3	9.300	1.600	282.8
100.00	3.00	1206	1371.4	18.816	1.2669	.5014	447	.00028	3.427	306.5	10.923	1.626	287.2
200.00	1.50	1039	1289.3	18.816	1.2810	.4814	402	.00025	3.828	315.4	18.057	1.695	299.4
300.00	1.00	950	1246.7	18.816	1.2894	.4705	377	.00023	4.072	319.8	24.258	1.729	305.5
500.00	.60	846	1198.3	18.816	1.3001	.4575	347	.00020	4.394	324.8	35.206	1.768	312.3
800.00	.37	758	1158.5	18.816	1.3096	.4468	320	.00019	4.707	328.8	49.600	1.799	317.8
1000.00	.30	719	1141.2	18.816	1.3139	.4421	308	.00018	4.862	330.5	58.362	1.812	320.2
1500.00	.20	652	1111.8	18.816	1.3212	.4344	286	.00016	5.154	333.4	78.422	1.835	324.2
R = 0.95, PERCENT FUEL = 42.76, O/F = 1.339													
1.00	300.00	2913	2250.6	19.201	1.2079	0.6014	810	0.00059					
1.05	285.71	2889	2236.0	19.201	1.2082	.6006	805	.00059	0.285	400.0	2.173	0.203	35.7
1.60	187.50	2686	2114.5	19.201	1.2111	.5936	768	.00056	.899	219.9	1.010	.618	108.8
1.78	168.62	2636	2085.3	19.201	1.2119	.5918	759	.00055	1.000	218.9	1.000	.681	119.9
2.00	150.00	2583	2053.7	19.201	1.2128	.5899	748	.00054	1.102	219.7	1.009	.743	130.9
10.00	30.00	1932	1679.7	19.201	1.2281	.5572	618	.00042	2.156	261.9	2.217	1.266	222.9
20.00	15.00	1696	1549.7	19.201	1.2371	.5400	567	.00038	2.541	277.9	3.512	1.403	247.0
20.41	14.70	1689	1546.1	19.201	1.2374	.5395	565	.00038	2.552	278.3	3.561	1.406	247.6
40.00	7.50	1481	1435.9	19.201	1.2476	.5215	517	.00034	2.919	291.3	5.691	1.512	266.3
40.83	7.35	1475	1432.8	19.201	1.2479	.5209	516	.00034	2.930	291.7	5.774	1.515	266.8
80.00	3.75	1287	1336.7	19.201	1.2598	.5019	470	.00030	3.300	302.6	9.341	1.602	282.0
100.00	3.00	1229	1307.7	19.201	1.2640	.4956	455	.00028	3.425	305.8	10.974	1.627	286.4
200.00	1.50	1060	1225.6	19.201	1.2780	.4758	410	.00025	3.823	314.6	18.161	1.696	298.6
300.00	1.00	970	1183.1	19.201	1.2864	.4649	385	.00023	4.066	319.1	24.414	1.731	304.8
500.00	.60	864	1134.6	19.201	1.2970	.4519	355	.00021	4.386	324.1	35.461	1.770	311.6
800.00	.37	775	1094.8	19.201	1.3066	.4410	328	.00019	4.697	328.1	49.995	1.801	317.1
1000.00	.30	735	1077.4	19.201	1.3110	.4363	315	.00018	4.850	329.9	58.846	1.815	319.5
1500.00	.20	667	1047.9	19.201	1.3185	.4284	293	.00016	5.140	332.8	79.117	1.837	323.5

TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 1500

FOR LIQUID AMMONIA WITH LIQUID OXYGEN

(b) Continued. Combustion-chamber pressure, 300 pounds per square inch absolute; frozen composition during isentropic expansion

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Molecular weight, $\mathcal{M}$	Isentropic exponent, γ	Specific heat, c_p, cal/(g)(°K)	Absolute viscosity, μ, micropoises	Thermal conductivity, k, cal/(sec)(cm)(°K)	Mach number, M	Specific impulse, I_{vac}, (lb)(sec)/lb	Area ratio, ε	Thrust coefficient, C_F	Specific impulse, I, (lb)(sec)/lb
R = 1.00, PERCENT FUEL = 41.51, O/F = 1.409													
1.00	300.00	2928	2185.7	19.542	1.2072	0.5924	817	0.00059					
1.05	285.71	2904	2171.3	19.542	1.2075	.5917	815	.00058	0.285	397.5	2.172	0.203	35.5
1.60	187.50	2700	2051.3	19.542	1.2104	.5849	775	.00055	.899	218.6	1.010	.618	108.2
1.78	168.67	2650	2022.5	19.542	1.2112	.5831	766	.00054	1.000	217.6	1.000	.681	119.2
2.00	150.00	2597	1991.2	19.542	1.2121	.5812	756	.00054	1.102	218.4	1.009	.743	130.1
10.00	30.00	1945	1621.7	19.542	1.2271	.5494	625	.00042	2.156	260.4	2.219	1.266	221.5
20.00	15.00	1707	1493.1	19.542	1.2360	.5325	575	.00038	2.541	276.3	3.516	1.403	245.5
20.41	14.70	1700	1489.6	19.542	1.2363	.5320	571	.00038	2.552	276.7	3.565	1.406	246.1
40.00	7.50	1492	1380.5	19.542	1.2463	.5145	523	.00034	2.918	289.6	5.700	1.513	264.7
40.83	7.35	1486	1377.4	19.542	1.2467	.5139	522	.00033	2.929	290.0	5.783	1.515	265.2
80.00	3.75	1298	1282.3	19.542	1.2584	.4952	475	.00030	3.299	300.9	9.360	1.602	280.4
100.00	3.00	1239	1253.5	19.542	1.2626	.4890	460	.00028	3.423	304.1	10.999	1.627	284.8
200.00	1.50	1070	1172.2	19.542	1.2764	.4695	416	.00025	3.821	312.9	18.211	1.697	297.0
300.00	1.00	979	1130.0	19.542	1.2849	.4587	390	.00023	4.063	317.4	24.489	1.732	303.1
500.00	.60	872	1082.0	19.542	1.2955	.4458	359	.00021	4.382	322.4	35.585	1.771	309.9
800.00	.37	783	1042.5	19.542	1.3051	.4350	332	.00019	4.692	326.4	50.188	1.802	315.4
1000.00	.30	743	1025.2	19.542	1.3095	.4302	319	.00018	4.844	328.1	59.083	1.816	317.8
1500.00	.20	674	996.0	19.542	1.3171	.4224	297	.00016	5.133	331.0	79.460	1.838	321.8
R = 1.10, PERCENT FUEL = 39.22, O/F = 1.550													
1.00	300.00	2913	2066.7	20.113	1.2075	0.5750	823	0.00057					
1.05	285.71	2889	2052.7	20.113	1.2078	.5743	818	.00057	0.285	390.9	2.172	0.203	34.9
1.60	187.50	2686	1936.8	20.113	1.2107	.5677	780	.00054	.899	214.9	1.010	.618	106.3
1.78	168.65	2637	1908.9	20.113	1.2115	.5660	771	.00053	1.000	213.9	1.000	.681	117.2
2.00	150.00	2583	1878.7	20.113	1.2123	.5641	761	.00052	1.102	214.7	1.009	.743	127.9
10.00	30.00	1934	1521.6	20.113	1.2274	.5332	629	.00041	2.156	256.0	2.218	1.266	217.8
20.00	15.00	1697	1397.4	20.113	1.2363	.5169	577	.00037	2.541	271.6	3.514	1.403	241.3
20.41	14.70	1691	1394.0	20.113	1.2366	.5164	575	.00037	2.552	272.0	3.564	1.406	241.9
40.00	7.50	1483	1288.6	20.113	1.2466	.4994	526	.00033	2.919	284.7	5.697	1.512	260.2
40.83	7.35	1477	1285.6	20.113	1.2470	.4988	525	.00033	2.930	285.1	5.780	1.515	260.7
80.00	3.75	1290	1193.7	20.113	1.2587	.4808	478	.00029	3.299	295.7	9.354	1.602	275.6
100.00	3.00	1232	1166.0	20.113	1.2628	.4748	468	.00028	3.424	298.9	10.992	1.627	280.0
200.00	1.50	1063	1087.5	20.113	1.2766	.4559	418	.00024	3.822	307.6	18.199	1.697	291.9
300.00	1.00	973	1046.7	20.113	1.2850	.4455	393	.00022	4.064	312.0	24.472	1.732	297.9
500.00	.60	867	1000.3	20.113	1.2956	.4330	362	.00020	4.383	316.9	35.559	1.771	304.6
800.00	.37	778	962.2	20.113	1.3052	.4225	334	.00018	4.693	320.8	50.151	1.802	310.0
1000.00	.30	738	945.4	20.113	1.3096	.4179	322	.00017	4.846	322.5	59.040	1.815	312.4
1500.00	.20	670	917.3	20.113	1.3172	.4103	299	.00016	5.135	325.4	79.401	1.838	316.3
R = 1.20, PERCENT FUEL = 37.16, O/F = 1.691													
1.00	300.00	2871	1960.2	20.593	1.2087	0.5589	822	0.00056					
1.05	285.71	2847	1946.7	20.593	1.2090	.5582	818	.00055	0.285	383.5	2.173	0.203	34.2
1.60	187.50	2646	1835.1	20.593	1.2120	.5517	779	.00052	.899	210.8	1.010	.618	104.3
1.78	168.57	2597	1808.2	20.593	1.2128	.5500	770	.00052	1.000	209.8	1.000	.681	115.0
2.00	150.00	2545	1779.2	20.593	1.2136	.5483	760	.00051	1.102	210.6	1.009	.744	125.5
10.00	30.00	1902	1435.9	20.593	1.2291	.5177	627	.00040	2.156	251.0	2.215	1.266	213.6
20.00	15.00	1668	1316.6	20.593	1.2381	.5019	575	.00036	2.541	266.2	3.507	1.402	236.6
20.41	14.70	1662	1313.3	20.593	1.2383	.5014	573	.00036	2.553	266.6	3.557	1.406	237.2
40.00	7.50	1457	1212.2	20.593	1.2486	.4846	524	.00032	2.920	279.1	5.682	1.512	255.1
40.83	7.35	1451	1209.4	20.593	1.2490	.4841	523	.00032	2.931	279.4	5.765	1.515	255.6
80.00	3.75	1265	1121.3	20.593	1.2607	.4667	476	.00028	3.301	289.8	9.322	1.601	270.2
100.00	3.00	1208	1094.7	20.593	1.2649	.4608	461	.00027	3.426	292.9	10.952	1.626	274.4
200.00	1.50	1042	1019.5	20.593	1.2787	.4427	416	.00023	3.826	301.4	18.119	1.695	286.1
300.00	1.00	953	980.6	20.593	1.2870	.4327	391	.00022	4.069	305.7	24.354	1.730	292.0
500.00	.60	849	936.2	20.593	1.2976	.4207	360	.00019	4.390	310.4	35.368	1.769	298.5
800.00	.37	761	899.7	20.593	1.3071	.4107	332	.00018	4.701	314.3	49.859	1.800	303.8
1000.00	.30	722	883.6	20.593	1.3114	.4064	319	.00017	4.855	315.9	58.683	1.814	306.0
1500.00	.20	655	856.8	20.593	1.3189	.3991	297	.00015	5.145	318.7	78.894	1.836	309.8
R = 1.50, PERCENT FUEL = 32.12, O/F = 2.114													
1.00	300.00	2728	1698.4	21.784	1.2133	0.5189	809	0.00051					
1.05	285.71	2705	1686.3	21.784	1.2137	.5182	805	.00051	0.284	363.4	2.176	0.203	32.4
1.60	187.50	2510	1586.2	21.784	1.2168	.5120	767	.00048	.898	199.6	1.010	.619	98.8
1.78	168.29	2462	1561.7	21.784	1.2177	.5103	757	.00047	1.000	198.7	1.000	.683	109.1
2.00	150.00	2412	1536.1	21.784	1.2186	.5085	747	.00046	1.100	199.4	1.009	.744	118.9
10.00	30.00	1792	1229.3	21.784	1.2355	.4786	614	.00036	2.155	237.2	2.204	1.265	202.0
20.00	15.00	1567	1123.2	21.784	1.2449	.4638	561	.00032	2.543	251.5	3.481	1.401	223.7
20.41	14.70	1561	1120.3	21.784	1.2452	.4633	560	.00032	2.554	251.9	3.530	1.404	224.3
40.00	7.50	1364	1030.6	21.784	1.2560	.4476	511	.00029	2.923	263.5	5.625	1.509	241.1
40.83	7.35	1358	1028.1	21.784	1.2564	.4471	509	.00029	2.935	263.8	5.706	1.512	241.5
80.00	3.75	1181	950.3	21.784	1.2683	.4312	463	.00025	3.309	273.5	9.203	1.598	255.1
100.00	3.00	1126	926.8	21.784	1.2726	.4258	448	.00024	3.435	276.4	10.802	1.623	259.1
200.00	1.50	968	860.7	21.784	1.2864	.4097	405	.00021	3.840	284.2	17.821	1.691	270.0
300.00	1.00	884	826.5	21.784	1.2946	.4008	378	.00019	4.088	288.2	23.916	1.725	275.5
500.00	.60	785	787.6	21.784	1.3050	.3904	347	.00018	4.414	292.6	34.666	1.763	281.5
800.00	.37	703	755.7	21.784	1.3140	.3817	320	.00016	4.731	296.1	48.787	1.793	286.4
1000.00	.30	666	741.8	21.784	1.3182	.3779	308	.00015	4.887	297.7	57.379	1.807	288.5
1500.00	.20	604	718.3	21.784	1.3254	.3715	285	.00014	5.183	300.2	77.038	1.829	292.0

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TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 1500

FOR LIQUID AMMONIA WITH LIQUID OXYGEN

(b) Concluded. Combustion-chamber pressure, 300 pounds per square inch absolute; frozen composition during isentropic expansion

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Molecular weight, $\mathscr{M}$	Isentropic exponent, γ	Specific heat, c_p, $\frac{cal}{(g)(^{\circ}K)}$	Absolute viscosity, μ, micropoises	Thermal conductivity, k, $\frac{cal}{(sec)(cm)(^{\circ}K)}$	Mach number, M	Specific impulse, I_{vac}, $\frac{(lb)(sec)}{lb}$	Area ratio, ϵ	Thrust coefficient, C_F	Specific impulse, I, $\frac{(lb)(sec)}{lb}$
R = 2.00, PERCENT FUEL = 26.19, O/F = 2.818													
1.00	300.00	2515	1391.0	23.307	1.2208	0.4714	783	0.00045					
1.05	285.71	2493	1380.6	23.307	1.2212	.4707	778	.00045	0.283	337.3	2.181	0.204	30.1
1.60	187.50	2309	1294.4	23.307	1.2249	.4643	740	.00042	.895	185.1	1.010	.620	91.7
1.79	167.81	2262	1272.7	23.307	1.2260	.4626	730	.00042	1.000	184.2	1.000	.686	101.4
2.00	150.00	2216	1251.3	23.307	1.2270	.4608	720	.00041	1.098	184.8	1.008	.745	110.2
10.00	30.00	1630	989.1	23.307	1.2455	.4325	588	.00032	2.155	219.3	2.186	1.264	187.0
20.00	15.00	1419	899.1	23.307	1.2556	.4185	536	.00028	2.545	232.3	3.440	1.399	206.9
20.41	14.70	1413	896.6	23.307	1.2562	.4181	534	.00028	2.556	232.7	3.487	1.402	207.4
40.00	7.50	1229	821.0	23.307	1.2673	.4042	486	.00025	2.930	243.2	5.535	1.506	222.7
40.83	7.35	1224	818.8	23.307	1.2677	.4038	485	.00025	2.942	243.5	5.615	1.509	223.1
80.00	3.75	1059	753.5	23.307	1.2802	.3896	439	.00022	3.322	252.2	9.020	1.592	235.5
100.00	3.00	1008	733.8	23.307	1.2845	.3850	424	.00021	3.450	254.8	10.572	1.617	239.1
200.00	1.50	862	678.6	23.307	1.2980	.3714	380	.00018	3.864	261.8	17.371	1.683	249.0
300.00	1.00	785	650.2	23.807	1.3061	.3638	356	.00017	4.117	265.4	23.257	1.717	253.9
500.00	.60	695	618.0	23.307	1.3159	.3552	326	.00015	4.452	269.3	33.615	1.753	259.3
800.00	.37	620	591.6	23.307	1.3247	.3478	299	.00014	4.777	272.5	47.191	1.783	263.7
1000.00	.30	587	580.2	23.307	1.3287	.3447	287	.00013	4.938	273.8	55.438	1.796	265.6
1500.00	.20	531	560.9	23.307	1.3354	.3394	266	.00012	5.242	276.1	74.282	1.817	268.8
R = 3.00, PERCENT FUEL = 19.13, O/F = 4.227													
1.00	300.00	2163	1024.7	25.320	1.2354	0.4119	727	0.00037					
1.05	285.71	2143	1016.4	25.320	1.2359	.4112	722	.00037	0.282	300.0	2.189	0.204	26.8
1.60	187.50	1976	948.4	25.320	1.2402	.4053	685	.00034	.891	164.3	1.011	.622	81.5
1.80	166.92	1932	930.6	25.320	1.2415	.4035	675	.00034	1.000	163.4	1.000	.691	90.5
2.00	150.00	1892	914.5	25.320	1.2427	.4019	665	.00033	1.093	163.9	1.007	.747	97.9
10.00	30.00	1368	710.1	25.320	1.2641	.3757	536	.00025	2.154	193.7	2.154	1.263	165.5
20.00	15.00	1180	640.9	25.320	1.2751	.3638	485	.00022	2.549	204.8	3.367	1.395	182.8
20.41	14.70	1175	639.0	25.320	1.2754	.3634	484	.00022	2.561	205.1	3.413	1.398	183.2
40.00	7.50	1014	581.3	25.320	1.2874	.3515	438	.00020	2.942	214.0	5.381	1.499	196.4
40.83	7.35	1009	579.6	25.320	1.2878	.3512	437	.00020	2.954	214.3	5.457	1.502	196.8
80.00	3.75	866	530.2	25.320	1.3003	.3398	393	.00017	3.345	221.7	8.707	1.583	207.4
100.00	3.00	822	515.4	25.320	1.3045	.3361	379	.00016	3.478	223.8	10.183	1.607	210.5
200.00	1.50	698	474.2	25.320	1.3180	.3253	337	.00014	3.906	229.8	16.615	1.671	218.9
300.00	1.00	632	453.0	25.320	1.3259	.3193	314	.00013	4.169	232.7	22.157	1.702	223.0
500.00	.60	557	429.2	25.320	1.3354	.3125	286	.00012	4.518	236.0	31.869	1.737	227.6
800.00	.37	494	409.9	25.320	1.3435	.3070	261	.00011	4.858	238.6	44.547	1.765	231.3
1000.00	.30	467	401.4	25.320	1.3473	.3044	250	.00010	5.026	239.7	52.227	1.777	232.9
1500.00	.20	420	387.3	25.320	1.3533	.3006	230	.00009	5.345	241.6	69.732	1.797	235.5
R = 4.00, PERCENT FUEL = 15.07, O/F = 5.636													
1.00	300.00	1875	814.0	26.561	1.2489	0.3754	672	0.00031					
1.05	285.71	1857	807.1	26.561	1.2494	.3747	667	.00031	0.280	272.6	2.198	0.205	24.3
1.60	187.50	1706	751.0	26.561	1.2545	.3688	631	.00029	.887	149.0	1.012	.624	74.0
1.81	166.11	1664	735.8	26.561	1.2559	.3672	621	.00029	1.000	148.2	1.000	.695	82.5
2.00	150.00	1630	723.2	26.561	1.2571	.3658	612	.00028	1.088	148.6	1.007	.749	88.9
10.00	30.00	1160	556.5	26.561	1.2804	.3417	488	.00021	2.153	174.9	2.126	1.262	149.7
20.00	15.00	994	500.8	26.561	1.2923	.3308	440	.00019	2.553	184.7	3.304	1.392	165.1
20.41	14.70	989	499.2	26.561	1.2926	.3305	439	.00019	2.565	184.9	3.349	1.395	165.5
40.00	7.50	848	453.1	26.561	1.3048	.3203	395	.00016	2.953	192.8	5.250	1.494	177.2
40.83	7.35	844	451.8	26.561	1.3052	.3200	393	.00016	2.965	193.0	5.324	1.497	177.5
80.00	3.75	719	412.5	26.561	1.3182	.3100	352	.00014	3.365	199.4	8.445	1.576	186.9
100.00	3.00	681	400.9	26.561	1.3225	.3068	338	.00014	3.502	201.3	9.857	1.598	189.6
200.00	1.50	574	368.4	26.561	1.3360	.2975	299	.00012	3.942	206.4	15.988	1.660	196.9
300.00	1.00	518	351.9	26.561	1.3434	.2927	277	.00011	4.215	208.9	21.247	1.690	200.5
500.00	.60	454	333.3	26.561	1.3525	.2870	251	.00010	4.576	211.7	30.433	1.724	204.5
800.00	.37	401	318.3	26.561	1.3593	.2830	228	.00009	4.931	214.0	42.383	1.751	207.7
1000.00	.30	378	311.8	26.561	1.3619	.2815	217	.00008	5.107	214.9	49.612	1.762	209.0
1500.00	.20	339	301.0	26.561	1.3659	.2793	199	.00007	5.441	216.5	66.074	1.781	211.3
R = 5.00, PERCENT FUEL = 12.43, O/F = 7.046													
1.00	300.00	1640	677.0	27.397	1.2611	0.3504	621	0.00027					
1.05	285.71	1624	671.3	27.397	1.2617	.3497	617	.00027	0.279	251.0	2.205	0.206	22.4
1.60	187.50	1487	623.8	27.397	1.2671	.3441	582	.00025	.883	137.0	1.013	.625	68.1
1.81	165.38	1448	610.4	27.397	1.2688	.3424	572	.00025	1.000	136.1	1.000	.699	76.1
2.00	150.00	1418	600.3	27.397	1.2701	.3410	564	.00024	1.084	136.5	1.006	.751	81.7
10.00	30.00	995	460.6	27.397	1.2949	.3185	446	.00018	2.152	160.1	2.103	1.261	137.2
20.00	15.00	848	414.3	27.397	1.3071	.3087	400	.00016	2.557	168.9	3.252	1.389	151.2
20.41	14.70	844	413.0	27.397	1.3075	.3084	399	.00016	2.568	169.1	3.295	1.392	151.6
40.00	7.50	719	375.0	27.397	1.3204	.2989	357	.00014	2.963	176.1	5.140	1.489	162.1
40.83	7.35	715	373.9	27.397	1.3208	.2987	355	.00014	2.975	176.3	5.211	1.492	162.4
80.00	3.75	606	341.8	27.397	1.3341	.2896	316	.00012	3.382	182.0	8.225	1.569	170.8
100.00	3.00	573	332.2	27.397	1.3385	.2868	303	.00011	3.522	183.6	9.584	1.591	173.2
200.00	1.50	479	305.8	27.397	1.3515	.2789	266	.00010	3.975	188.1	15.466	1.651	179.7
300.00	1.00	431	292.5	27.397	1.3584	.2749	245	.00009	4.255	190.4	20.494	1.680	182.9
500.00	.60	376	277.5	27.397	1.3652	.2711	221	.00008	4.630	192.8	29.258	1.713	186.4
800.00	.37	332	265.5	27.397	1.3699	.2686	200	.00007	4.998	194.8	40.647	1.738	189.2
1000.00	.30	312	260.3	27.397	1.3717	.2677	190	.00007	5.180	195.6	47.533	1.749	190.4
1500.00	.20	280	251.6	27.397	1.3741	.2664	174	.00006	5.525	197.0	63.206	1.768	192.4

TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 1500

FOR LIQUID AMMONIA WITH LIQUID OXYGEN

(c) Combustion-chamber pressure, 600 pounds per square inch absolute; equilibrium composition during isentropic expansion

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Molecular weight, $\mathcal{M}$	Isentropic exponent, γ	Specific heat, c_p, $\frac{cal}{(g)(°K)}$	Absolute viscosity, μ, micropoises	Thermal conductivity, k, cal/(sec)(cm)(°K)	Mach number, M	Specific impulse, I_{vac}, $\frac{(lb)(sec)}{lb}$	Area ratio, ε	Thrust coefficient, C_F	Specific impulse, I, $\frac{(lb)(sec)}{lb}$
R = 0.40, PERCENT FUEL = 63.95, O/F = 0.564													
1.00	600.00	1349	3350.2	13.316	1.2956	0.6540	453	0.00038					
1.05	571.43	1334	3340.4	13.316	1.2966	.6524	450	.00038	0.275	326.2	2.226	0.208	29.1
1.60	375.00	1210	3260.5	13.316	1.3052	.6381	421	.00035	.872	177.3	1.015	.630	88.3
1.84	326.41	1171	3235.9	13.316	1.3082	.6335	412	.00034	1.000	176.0	1.000	.712	99.7
2.00	300.00	1148	3221.3	13.316	1.3100	.6307	406	.00033	1.072	176.3	1.004	.756	105.9
10.00	60.00	772	2993.1	13.316	1.3421	.5855	309	.00024	2.149	204.7	2.030	1.258	176.3
20.00	30.00	646	2919.9	13.316	1.3530	.5720	272	.00021	2.569	215.2	3.093	1.381	193.5
20.41	29.39	643	2917.9	13.316	1.3532	.5717	271	.00021	2.581	215.4	3.133	1.384	193.9
40.00	15.00	538	2858.8	13.316	1.3617	.5618	237	.00018	2.998	223.7	4.823	1.476	206.8
40.83	14.70	535	2857.1	13.316	1.3619	.5616	236	.00018	3.011	223.9	4.888	1.478	207.1
80.00	7.50	447	2807.9	13.316	1.3680	.5547	206	.00015	3.447	230.6	7.629	1.550	217.2
100.00	6.00	421	2793.5	13.316	1.3696	.5530	196	.00015	3.597	232.5	8.863	1.571	220.1
200.00	3.00	349	2753.8	13.316	1.3745	.5478	168	.00012	4.083	237.7	14.191	1.626	227.8
300.00	2.00	312	2733.8	13.316	1.3767	.5454	154	.00011	4.383	240.3	18.744	1.653	231.6
500.00	1.20	271	2711.6	13.316	1.3793	.5427	136	.00010	4.781	243.2	26.680	1.682	235.7
800.00	.75	238	2695.7	13.316	1.3842	.5377	122	.00009	5.163	245.5	36.978	1.705	239.0
1000.00	.60	224	2686.0	13.316	1.3874	.5344	115	.00008	5.351	246.4	43.187	1.715	240.4
1500.00	.40	200	2673.2	13.316	1.3925	.5294	104	.00007	5.708	248.0	57.266	1.732	242.7
R = 0.50, PERCENT FUEL = 58.67, O/F = 0.705													
1.00	600.00	1784	3075.9	14.516	1.2618	0.6602	555	0.00046					
1.05	571.43	1766	3064.0	14.516	1.2626	.6585	551	.00046	0.279	359.6	2.206	0.206	32.1
1.60	375.00	1617	2966.5	14.516	1.2696	.6448	520	.00042	.882	196.3	1.013	.626	97.5
1.82	330.41	1574	2938.9	14.516	1.2718	.6407	511	.00041	1.000	195.0	1.000	.700	109.2
2.00	300.00	1542	2918.3	14.516	1.2735	.6375	503	.00041	1.083	195.5	1.006	.751	117.1
10.00	60.00	1075	2632.4	14.516	1.3057	.5847	394	.00030	2.149	229.0	2.090	1.260	196.4
20.00	30.00	911	2538.4	14.516	1.3200	.5646	351	.00026	2.555	241.3	3.218	1.387	216.3
20.41	29.39	906	2535.8	14.516	1.3205	.5641	350	.00026	2.567	241.7	3.261	1.390	216.8
40.00	15.00	768	2458.9	14.516	1.3335	.5474	311	.00022	2.967	251.4	5.065	1.486	231.7
40.83	14.70	764	2456.7	14.516	1.3339	.5469	310	.00022	2.979	251.7	5.134	1.489	232.1
80.00	7.50	644	2392.0	14.516	1.3450	.5337	274	.00019	3.396	259.7	8.071	1.565	243.9
100.00	6.00	608	2372.9	14.516	1.3482	.5301	262	.00018	3.539	262.0	9.396	1.586	247.3
200.00	3.00	508	2320.1	14.516	1.3571	.5202	228	.00016	4.003	268.2	15.126	1.645	256.4
300.00	2.00	456	2293.4	14.516	1.3609	.5162	210	.00014	4.292	271.3	20.033	1.674	260.9
500.00	1.20	398	2263.5	14.516	1.3649	.5121	188	.00013	4.673	274.8	28.602	1.705	265.9
800.00	.75	351	2239.5	14.516	1.3682	.5087	169	.00012	5.045	277.5	39.757	1.730	269.8
1000.00	.60	330	2229.1	14.516	1.3697	.5072	161	.00011	5.228	278.7	46.508	1.741	271.4
1500.00	.40	296	2211.7	14.516	1.3715	.5054	146	.00010	5.576	280.6	61.884	1.759	274.2
R = 0.60, PERCENT FUEL = 54.19, O/F = 0.845													
1.00	600.00	2171	2843.5	15.710	1.2352	0.6700	640	0.00055					
1.05	571.43	2151	2830.1	15.711	1.2361	.6675	636	.00052	0.282	381.6	2.191	0.205	34.1
1.60	375.00	1983	2720.1	15.714	1.2432	.6486	603	.00049	.890	208.9	1.012	.622	103.6
1.80	333.38	1938	2690.9	15.715	1.2451	.6440	594	.00048	1.000	207.7	1.000	.692	115.2
2.00	300.00	1898	2665.3	15.715	1.2469	.6399	586	.00047	1.091	208.4	1.007	.748	124.5
10.00	60.00	1361	2336.0	15.716	1.2746	.5870	469	.00035	2.151	245.8	2.140	1.262	210.1
20.00	30.00	1169	2225.3	15.716	1.2883	.5650	422	.00031	2.548	259.7	3.330	1.393	231.9
20.41	29.39	1164	2222.2	15.716	1.2887	.5643	421	.00030	2.560	260.0	3.375	1.396	232.5
40.00	15.00	998	2130.4	15.716	1.3029	.5439	378	.00027	2.945	271.1	5.295	1.496	249.1
40.83	14.70	993	2127.9	15.716	1.3033	.5433	377	.00026	2.957	271.4	5.369	1.498	249.5
80.00	7.50	847	2049.7	15.716	1.3171	.5252	337	.00023	3.355	280.5	8.518	1.578	262.8
100.00	6.00	803	2026.5	15.716	1.3215	.5197	324	.00022	3.491	283.2	9.943	1.601	266.6
200.00	3.00	676	1961.8	15.716	1.3340	.5050	286	.00019	3.932	290.4	16.131	1.663	277.0
300.00	2.00	611	1928.8	15.716	1.3404	.4979	265	.00017	4.205	294.0	21.448	1.694	282.1
500.00	1.20	536	1891.9	15.716	1.3476	.4902	239	.00016	4.566	298.0	30.749	1.728	287.8
800.00	.75	474	1861.9	15.716	1.3531	.4845	217	.00014	4.919	301.2	42.879	1.755	292.3
1000.00	.60	447	1848.9	15.716	1.3552	.4824	207	.00013	5.094	302.5	50.228	1.767	294.2
1500.00	.40	402	1827.1	15.716	1.3588	.4789	190	.00012	5.425	304.8	66.991	1.786	297.4
R = 0.70, PERCENT FUEL = 50.34, O/F = 0.986													
1.00	600.00	2503	2644.0	16.876	1.2058	0.7252	711	0.00062					
1.05	571.43	2483	2629.7	16.879	1.2069	.7195	707	.00061	0.285	395.5	2.175	0.203	35.3
1.60	375.00	2309	2511.0	16.898	1.2167	.6770	674	.00056	.897	217.4	1.010	.619	107.6
1.78	336.30	2265	2481.7	16.901	1.2192	.6680	665	.00054	1.000	216.3	1.000	.683	118.9
2.00	300.00	2219	2451.6	16.904	1.2216	.6593	657	.00053	1.099	217.1	1.009	.744	129.4
10.00	60.00	1693	2089.3	16.916	1.2499	.5879	536	.00039	2.151	257.7	2.184	1.265	219.7
20.00	30.00	1418	1965.3	16.916	1.2619	.5661	487	.00035	2.542	272.8	3.428	1.397	243.0
20.41	29.39	1412	1961.9	16.916	1.2622	.5655	486	.00035	2.553	273.2	3.476	1.401	243.6
40.00	15.00	1224	1857.9	16.916	1.2750	.5447	440	.00030	2.928	285.5	5.502	1.504	261.6
40.83	14.70	1219	1854.9	16.916	1.2754	.5441	439	.00030	2.940	285.8	5.580	1.507	262.0
80.00	7.50	1051	1765.4	16.916	1.2893	.5236	396	.00027	3.323	295.9	8.936	1.590	276.5
100.00	6.00	999	1738.5	16.916	1.2940	.5171	382	.00025	3.459	298.9	10.465	1.614	280.7
200.00	3.00	851	1663.3	16.916	1.3083	.4986	341	.00022	3.872	307.0	17.127	1.680	292.1
300.00	2.00	773	1624.6	16.916	1.3164	.4888	318	.00020	4.130	311.1	22.881	1.712	297.8
500.00	1.20	683	1581.0	16.916	1.3257	.4781	290	.00018	4.472	315.6	32.983	1.749	304.1
800.00	.75	608	1545.4	16.916	1.3334	.4698	265	.00016	4.805	319.2	46.201	1.778	309.2
1000.00	.60	575	1529.9	16.916	1.3369	.4662	254	.00016	4.970	320.8	54.224	1.790	311.4
1500.00	.40	518	1503.9	16.916	1.3426	.4604	235	.00014	5.281	323.4	72.546	1.811	315.0

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TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 1500 FOR LIQUID AMMONIA WITH LIQUID OXYGEN

(c) Continued. Combustion-chamber pressure, 600 pounds per square inch absolute; equilibrium composition during isentropic expansion

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Molecular weight, $\mathcal{M}$	Isentropic exponent, γ	Specific heat, c_p, $\frac{cal}{(g)(°K)}$	Absolute viscosity, μ, micropoises	Thermal conductivity, k, cal/(sec)(cm)(°K)	Mach number, M	Specific impulse, I_{vac}, $\frac{(lb)(sec)}{lb}$	Area ratio, ε	Thrust coefficient, C_F	Specific impulse, I, $\frac{(lb)(sec)}{lb}$
R = 0.80, PERCENT FUEL = 47.01, O/F = 1.127													
1.00	600.00	2760	2471.0	17.957	1.1740	0.8755	767	0.00078					
1.05	571.43	2741	2456.2	17.965	1.1750	.8653	763	.00077	0.289	403.0	2.156	0.201	35.9
1.60	375.00	2580	2332.4	18.024	1.1847	.7831	733	.00067	.907	222.5	1.008	.614	109.8
1.76	340.01	2542	2304.8	18.035	1.1872	.7659	726	.00066	1.000	221.6	1.000	.673	120.3
2.00	300.00	2493	2270.1	18.048	1.1904	.7451	717	.00063	1.109	222.6	1.011	.740	132.2
10.00	60.00	1891	1883.3	18.113	1.2283	.5932	597	.00044	2.147	266.1	2.233	1.265	226.1
20.00	30.00	1658	1748.5	18.116	1.2400	.5673	547	.00039	2.531	282.3	3.531	1.403	250.7
20.41	29.39	1652	1744.8	18.116	1.2403	.5666	545	.00038	2.542	282.7	3.581	1.406	251.4
40.00	15.00	1447	1630.6	18.116	1.2516	.5458	498	.00034	2.909	296.0	5.712	1.513	270.4
40.83	14.70	1441	1627.3	18.116	1.2519	.5452	497	.00034	2.920	296.3	5.795	1.516	270.9
80.00	7.50	1255	1528.0	18.116	1.2642	.5249	452	.00030	3.292	307.4	9.356	1.602	286.5
100.00	6.00	1197	1498.0	18.116	1.2685	.5182	438	.00029	3.418	310.6	10.986	1.628	291.0
200.00	3.00	1031	1413.4	18.116	1.2827	.4977	394	.00025	3.819	319.6	18.144	1.697	303.4
300.00	2.00	942	1369.5	18.116	1.2911	.4865	369	.00023	4.064	324.1	24.364	1.732	309.6
500.00	1.20	838	1319.7	18.116	1.3017	.4733	340	.00021	4.387	329.1	35.340	1.770	316.5
800.00	.75	751	1278.8	18.116	1.3110	.4624	313	.00019	4.700	333.2	49.765	1.802	322.1
1000.00	.60	712	1260.9	18.116	1.3153	.4576	301	.00018	4.855	335.0	58.545	1.815	324.3
1500.00	.40	645	1230.8	18.116	1.3225	.4499	283	.00017	5.148	337.9	78.642	1.838	328.5
R = 0.90, PERCENT FUEL = 44.09, O/F = 1.268													
1.00	600.00	2922	2319.5	18.893	1.1494	1.1223	805	0.00101					
1.05	571.43	2905	2304.6	18.907	1.1498	1.1114	802	.00100	0.292	404.4	2.138	0.199	36.1
1.60	375.00	2765	2179.4	19.020	1.1544	1.0129	776	.00089	.917	224.2	1.007	.610	110.4
1.74	343.86	2736	2154.6	19.041	1.1556	.9919	770	.00086	1.000	223.5	1.000	.662	119.8
2.00	300.00	2690	2116.0	19.073	1.1578	.9586	762	.00083	1.120	224.7	1.013	.736	133.1
10.00	60.00	2135	1713.6	19.289	1.2006	.6391	653	.00050	2.142	271.3	2.304	1.269	229.6
20.00	30.00	1896	1569.8	19.310	1.2181	.5800	603	.00043	2.512	288.6	3.674	1.412	255.4
20.41	29.39	1889	1565.9	19.310	1.2186	.5788	602	.00043	2.523	289.1	3.726	1.416	256.1
40.00	15.00	1670	1442.8	19.315	1.2311	.5490	554	.00038	2.880	303.3	5.982	1.527	276.2
40.83	14.70	1663	1439.3	19.315	1.2314	.5483	553	.00037	2.890	303.6	6.071	1.530	276.7
80.00	7.50	1462	1331.3	19.316	1.2426	.5270	506	.00033	3.252	315.6	9.869	1.621	293.2
100.00	6.00	1399	1298.4	19.316	1.2465	.5203	491	.00032	3.373	319.1	11.616	1.648	298.1
200.00	3.00	1217	1205.3	19.316	1.2590	.5001	441	.00028	3.760	328.9	19.337	1.721	311.4
300.00	2.00	1118	1156.6	19.316	1.2670	.4882	410	.00025	3.995	333.8	26.094	1.758	318.1
500.00	1.20	1003	1100.9	19.316	1.2774	.4737	371	.00022	4.301	339.4	38.086	1.800	325.6
800.00	.75	904	1054.8	19.316	1.2872	.4611	335	.00020	4.597	343.9	53.938	1.834	331.7
1000.00	.60	860	1034.6	19.316	1.2918	.4555	319	.00019	4.742	345.9	63.621	1.848	334.4
1500.00	.40	784	1000.3	19.316	1.3000	.4458	303	.00017	5.017	349.2	85.855	1.873	338.8
R = 0.95, PERCENT FUEL = 42.76, O/F = 1.339													
1.00	600.00	2963	2250.6	19.291	1.1426	1.2294	818	0.00111					
1.05	571.43	2948	2235.8	19.307	1.1427	1.2208	815	.00110	0.293	403.2	2.133	0.199	35.9
1.60	375.00	2815	2111.3	19.440	1.1445	1.1408	790	.00100	.920	223.8	1.006	.609	110.1
1.74	345.19	2790	2087.6	19.465	1.1450	1.1240	785	.00098	1.000	223.1	1.000	.659	119.1
2.00	300.00	2746	2048.0	19.506	1.1461	1.0946	776	.00095	1.124	224.4	1.014	.734	132.8
10.00	60.00	2241	1642.6	19.841	1.1784	.7248	677	.00058	2.144	272.5	2.348	1.272	230.0
20.00	30.00	2012	1495.1	19.895	1.2015	.6138	630	.00047	2.502	290.5	3.772	1.418	256.4
20.41	29.39	2005	1491.0	19.896	1.2021	.6115	629	.00046	2.512	291.0	3.826	1.422	257.1
40.00	15.00	1784	1363.9	19.912	1.2197	.5578	581	.00040	2.858	305.7	6.170	1.536	277.8
40.83	14.70	1778	1360.2	19.912	1.2201	.5567	580	.00040	2.868	306.1	6.262	1.539	278.3
80.00	7.50	1570	1247.9	19.915	1.2324	.5297	534	.00035	3.223	318.5	10.212	1.634	295.4
100.00	6.00	1505	1213.7	19.916	1.2362	.5225	518	.00034	3.342	322.1	12.031	1.661	300.4
200.00	3.00	1315	1116.3	19.916	1.2481	.5019	472	.00030	3.722	332.3	20.099	1.738	314.2
300.00	2.00	1212	1065.2	19.916	1.2555	.4903	446	.00027	3.952	337.5	27.182	1.776	321.2
500.00	1.20	1091	1006.5	19.916	1.2656	.4755	415	.00025	4.251	343.4	39.792	1.820	329.0
800.00	.75	987	957.9	19.916	1.2752	.4624	386	.00023	4.538	348.2	56.511	1.855	335.4
1000.00	.60	940	936.4	19.916	1.2798	.4564	373	.00022	4.679	350.2	66.746	1.870	338.2
1500.00	.40	859	900.0	19.916	1.2882	.4460	364	.00021	4.945	353.7	90.290	1.896	342.8
R = 0.975, PERCENT FUEL = 42.13, O/F = 1.374													
1.00	600.00	2975	2217.7	19.471	1.1409	1.2570	823	0.00114					
1.05	571.43	2960	2202.9	19.488	1.1409	1.2494	820	.00113	0.293	402.1	2.131	0.199	35.8
1.60	375.00	2829	2079.1	19.627	1.1419	1.1792	795	.00104	.921	223.3	1.006	.609	109.8
1.74	345.55	2804	2055.8	19.653	1.1422	1.1647	790	.00102	1.000	222.6	1.000	.658	118.7
2.00	300.00	2761	2016.0	19.697	1.1428	1.1390	782	.00099	1.126	224.0	1.014	.734	132.5
10.00	60.00	2280	1611.0	20.086	1.1650	.8037	686	.00064	2.149	272.5	2.367	1.273	229.8
20.00	30.00	2064	1462.3	20.172	1.1874	.6626	642	.00050	2.501	290.9	3.825	1.421	256.4
20.41	29.39	2058	1458.1	20.179	1.1881	.6591	641	.00050	2.511	291.4	3.881	1.425	257.1
40.00	15.00	1845	1329.0	20.206	1.2108	.5737	595	.00041	2.846	306.4	6.285	1.541	278.1
40.83	14.70	1836	1325.3	20.207	1.2114	.5719	594	.00041	2.856	306.8	6.379	1.544	278.7
80.00	7.50	1627	1210.9	20.215	1.2266	.5334	548	.00036	3.203	319.5	10.425	1.640	296.0
100.00	6.00	1561	1175.9	20.215	1.2307	.5251	532	.00035	3.321	323.3	12.290	1.669	301.1
200.00	3.00	1367	1076.2	20.216	1.2428	.5032	486	.00030	3.697	333.7	20.564	1.747	315.2
300.00	2.00	1262	1023.8	20.216	1.2499	.4916	460	.00028	3.924	339.1	27.839	1.786	322.3
500.00	1.20	1138	963.6	20.216	1.2597	.4768	428	.00026	4.220	345.1	40.811	1.831	330.3
800.00	.75	1031	913.6	20.216	1.2691	.4636	399	.00023	4.503	350.0	58.039	1.867	336.9
1000.00	.60	983	891.5	20.216	1.2737	.4575	386	.00022	4.642	352.1	68.596	1.883	339.7
1500.00	.40	900	854.0	20.216	1.2820	.4468	380	.00022	4.903	355.7	92.907	1.909	344.5

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TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 1500

FOR LIQUID AMMONIA WITH LIQUID OXYGEN

(c) Continued. Combustion-chamber pressure, 600 pounds per square inch absolute; equilibrium composition during isentropic expansion

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Molecular weight, $\mathcal{M}$	Isentropic exponent, γ	Specific heat, c_p, $\frac{cal}{(g)(^{\circ}K)}$	Absolute viscosity, μ, micropoises	Thermal conductivity, k, $\frac{cal}{(sec)(cm)(^{\circ}K)}$	Mach number, M	Specific impulse, I_{vac}, $\frac{(lb)(sec)}{lb}$	Area ratio, ϵ	Thrust coefficient, C_F	Specific impulse, I, $\frac{(lb)(sec)}{lb}$
R = 1.00, PERCENT FUEL = 41.51, O/F = 1.409													
1.00	600.00	2980	2185.7	19.638	1.1402	1.2619	826	0.00115					
1.05	571.43	2965	2171.1	19.655	1.1402	1.2547	823	.00114	0.293	400.8	2.131	0.199	35.7
1.60	375.00	2836	2048.0	19.798	1.1409	1.1885	798	.00105	.921	222.6	1.006	.609	109.5
1.74	345.69	2811	2025.0	19.824	1.1411	1.1750	794	.00103	1.000	221.9	1.000	.657	118.3
2.00	300.00	2768	1985.4	19.869	1.1416	1.1510	785	.00100	1.126	223.3	1.014	.734	132.0
10.00	60.00	2297	1582.3	20.284	1.1579	.8538	692	.00068	2.152	271.9	2.375	1.274	229.2
20.00	30.00	2094	1433.6	20.396	1.1727	.7326	650	.00056	2.508	290.5	3.857	1.422	255.8
20.41	29.39	2088	1429.4	20.399	1.1732	.7294	649	.00055	2.518	291.0	3.914	1.426	256.5
40.00	15.00	1888	1299.4	20.465	1.1917	.6340	606	.00046	2.848	306.4	6.387	1.544	277.7
40.83	14.70	1882	1295.6	20.467	1.1923	.6315	605	.00046	2.858	306.9	6.484	1.547	278.3
80.00	7.50	1684	1179.3	20.499	1.2118	.5650	561	.00039	3.190	319.9	10.670	1.645	295.9
100.00	6.00	1619	1143.6	20.505	1.2177	.5490	547	.00037	3.303	323.8	12.600	1.674	301.1
200.00	3.00	1425	1041.4	20.514	1.2343	.5119	501	.00032	3.665	334.6	21.162	1.754	315.5
300.00	2.00	1318	987.6	20.515	1.2428	.4963	473	.00029	3.886	340.1	28.690	1.795	322.9
500.00	1.20	1191	925.5	20.516	1.2530	.4798	436	.00026	4.176	346.3	42.126	1.841	331.1
800.00	.75	1082	873.8	20.516	1.2626	.4658	400	.00023	4.454	351.4	59.993	1.878	337.9
1000.00	.60	1032	851.0	20.516	1.2671	.4595	383	.00022	4.590	355.6	70.953	1.894	340.8
1500.00	.40	947	812.1	20.516	1.2754	.4485	375	.00021	4.847	357.3	96.219	1.922	345.7
R = 1.10, PERCENT FUEL = 39.22, O/F = 1.550													
1.00	600.00	2962	2066.7	20.207	1.1432	1.1481	831	0.00106					
1.05	571.43	2946	2052.6	20.223	1.1433	1.1398	828	.00105	0.293	393.8	2.133	0.199	35.1
1.60	375.00	2812	1933.8	20.357	1.1452	1.0656	802	.00095	.920	218.6	1.006	.609	107.6
1.74	345.11	2786	1911.1	20.381	1.1457	1.0505	797	.00093	1.000	217.9	1.000	.659	116.4
2.00	300.00	2742	1873.4	20.422	1.1466	1.0246	788	.00090	1.124	219.2	1.014	.735	129.7
10.00	60.00	2245	1486.5	20.771	1.1691	.7419	688	.00059	2.150	266.3	2.355	1.272	224.7
20.00	30.00	2031	1345.1	20.851	1.1844	.6513	643	.00050	2.509	284.2	3.806	1.419	250.6
20.41	29.39	2024	1341.1	20.853	1.1849	.6490	642	.00049	2.520	284.7	3.861	1.423	251.3
40.00	15.00	1819	1218.1	20.897	1.2016	.5836	597	.00042	2.857	299.4	6.274	1.539	271.7
40.83	14.70	1813	1214.5	20.898	1.2021	.5820	596	.00042	2.868	299.9	6.369	1.542	272.3
80.00	7.50	1615	1105.0	20.919	1.2186	.5356	551	.00036	3.208	312.3	10.451	1.638	289.3
100.00	6.00	1551	1071.5	20.923	1.2239	.5234	536	.00034	3.323	316.1	12.339	1.667	294.3
200.00	3.00	1362	975.7	20.929	1.2397	.4923	489	.00030	3.690	326.4	20.676	1.745	308.1
300.00	2.00	1258	925.3	20.930	1.2482	.4779	460	.00027	3.914	331.6	28.004	1.785	315.2
500.00	1.20	1134	867.3	20.931	1.2589	.4618	422	.00025	4.207	337.6	41.063	1.830	323.1
800.00	.75	1028	819.1	20.931	1.2687	.4483	386	.00022	4.489	342.4	58.399	1.866	329.5
1000.00	.60	980	797.8	20.931	1.2733	.4424	369	.00021	4.627	344.5	69.021	1.882	332.3
1500.00	.40	898	761.7	20.931	1.2817	.4320	357	.00020	4.888	348.0	93.482	1.908	337.0
R = 1.20, PERCENT FUEL = 37.16, O/F = 1.691													
1.00	600.00	2914	1960.2	20.677	1.1473	1.0323	829	0.00096					
1.05	571.43	2898	1946.6	20.692	1.1475	1.0248	826	.00095	0.292	386.1	2.136	0.199	34.4
1.60	375.00	2761	1832.5	20.813	1.1498	.9596	799	.00086	.918	214.2	1.007	.610	105.4
1.74	344.53	2733	1810.2	20.836	1.1504	.9464	794	.00085	1.000	213.5	1.000	.661	114.2
2.00	300.00	2689	1774.5	20.872	1.1515	.9249	785	.00082	1.122	214.7	1.013	.735	127.2
10.00	60.00	2182	1404.4	21.179	1.1741	.6953	680	.00055	2.150	260.4	2.343	1.272	219.9
20.00	30.00	1968	1269.7	21.249	1.1894	.6184	635	.00047	2.512	277.8	3.779	1.418	245.1
20.41	29.39	1962	1266.0	21.251	1.1899	.6163	633	.00046	2.522	278.3	3.834	1.421	245.8
40.00	15.00	1758	1149.1	21.289	1.2068	.5580	588	.00040	2.862	292.5	6.218	1.536	265.7
40.83	14.70	1752	1145.8	21.290	1.2073	.5564	587	.00040	2.872	292.9	6.312	1.540	266.2
80.00	7.50	1556	1042.0	21.308	1.2241	.5141	542	.00034	3.215	305.0	10.337	1.635	282.7
100.00	6.00	1494	1010.3	21.311	1.2295	.5028	527	.00033	3.331	308.6	12.190	1.663	287.5
200.00	3.00	1308	919.8	21.316	1.2452	.4742	481	.00028	3.702	318.5	20.395	1.740	300.9
300.00	2.00	1206	872.3	21.317	1.2538	.4609	455	.00026	3.928	323.6	27.591	1.779	307.7
500.00	1.20	1086	817.7	21.317	1.2645	.4457	422	.00024	4.225	329.3	40.395	1.823	315.3
800.00	.75	983	772.4	21.317	1.2743	.4331	394	.00022	4.511	333.9	57.370	1.859	321.5
1000.00	.60	937	752.5	21.317	1.2788	.4275	380	.00021	4.651	335.9	67.761	1.875	324.2
1500.00	.40	856	718.6	21.317	1.2872	.4178	373	.00020	4.916	339.3	91.669	1.901	328.7
R = 1.50, PERCENT FUEL = 32.12, O/F = 2.114													
1.00	600.00	2759	1698.4	21.847	1.1548	0.8534	815	0.00079					
1.05	571.43	2743	1686.2	21.859	1.1551	.8478	811	.00078	0.291	365.5	2.141	0.200	32.6
1.60	375.00	2603	1584.1	21.960	1.1585	.7989	783	.00071	.915	202.5	1.007	.611	99.7
1.75	343.44	2574	1563.5	21.979	1.1593	.7887	777	.00070	1.000	201.8	1.000	.664	108.3
2.00	300.00	2530	1532.4	22.008	1.1607	.7729	768	.00068	1.119	202.9	1.013	.736	120.2
10.00	60.00	2017	1204.2	22.246	1.1886	.5962	658	.00047	2.148	245.2	2.315	1.270	207.4
20.00	30.00	1803	1086.1	22.293	1.2061	.5367	610	.00040	2.513	261.1	3.711	1.414	230.8
20.41	29.39	1797	1082.9	22.294	1.2066	.5352	609	.00039	2.524	261.5	3.764	1.418	231.4
40.00	15.00	1596	981.2	22.316	1.2241	.4920	562	.00034	2.871	274.6	6.066	1.530	249.8
40.83	14.70	1591	978.3	22.317	1.2246	.4909	561	.00034	2.882	274.9	6.156	1.533	250.3
80.00	7.50	1401	888.8	22.326	1.2411	.4598	514	.00029	3.234	285.9	10.018	1.626	265.4
100.00	6.00	1341	861.6	22.327	1.2462	.4516	499	.00028	3.354	289.1	11.790	1.653	269.8
200.00	3.00	1166	784.3	22.329	1.2609	.4303	454	.00025	3.738	298.0	19.610	1.727	282.0
300.00	2.00	1071	744.0	22.329	1.2694	.4194	428	.00023	3.972	302.6	26.441	1.765	288.2
500.00	1.20	959	697.8	22.329	1.2798	.4071	396	.00021	4.280	307.7	38.555	1.807	295.1
800.00	.75	865	659.7	22.329	1.2893	.3966	367	.00019	4.576	311.8	54.560	1.841	300.6
1000.00	.60	822	643.0	22.329	1.2939	.3918	354	.00018	4.722	313.6	64.332	1.856	303.0
1500.00	.40	749	614.7	22.329	1.3020	.3837	343	.00017	4.998	316.5	86.765	1.881	307.1

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CQ-5

TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 1500

FOR LIQUID AMMONIA WITH LIQUID OXYGEN

(c) Concluded. Combustion-chamber pressure, 600 pounds per square inch absolute; equilibrium composition during isentropic expansion

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Molecular weight, $\mathcal{M}$	Isentropic exponent, γ	Specific heat, c_p, $\frac{cal}{(g)(°K)}$	Absolute viscosity, μ, micropoises	Thermal conductivity, k, $\frac{cal/(sec)}{(cm)(°K)}$	Mach number, M	Specific impulse, I_{vac}, $\frac{(lb)(sec)}{lb}$	Area ratio, ε	Thrust coefficient, C_F	Specific impulse, I, $\frac{(lb)(sec)}{lb}$
R = 2.00, PERCENT FUEL = 26.19, O/F = 2.818													
1.00	600.00	2536	1391.0	23.349	1.1672	0.6880	786	0.00062					
1.05	571.43	2519	1380.5	23.359	1.1678	.6833	783	.00062	0.290	338.8	2.150	0.200	30.2
1.60	375.00	2377	1292.9	23.434	1.1736	.6421	753	.00056	.911	187.3	1.008	.613	92.4
1.76	341.52	2345	1274.2	23.450	1.1751	.6330	746	.00055	1.000	186.6	1.000	.669	100.8
2.00	300.00	2302	1248.7	23.469	1.1773	.6205	737	.00053	1.114	187.5	1.011	.738	111.3
10.00	60.00	1783	971.7	23.617	1.2145	.4873	620	.00037	2.145	225.2	2.267	1.267	191.0
20.00	30.00	1572	874.0	23.638	1.2325	.4495	570	.00032	2.520	239.2	3.597	1.407	212.1
20.41	29.39	1566	871.3	23.638	1.2331	.4486	568	.00031	2.530	239.6	3.648	1.411	212.6
40.00	15.00	1374	788.2	23.645	1.2492	.4224	520	.00027	2.890	251.0	5.824	1.519	229.0
40.83	14.70	1369	785.9	23.646	1.2496	.4217	519	.00027	2.901	251.3	5.908	1.522	229.5
80.00	7.50	1193	713.6	23.648	1.2638	.4028	473	.00024	3.270	260.8	9.537	1.611	242.8
100.00	6.00	1138	691.7	23.648	1.2683	.3973	458	.00023	3.395	263.5	11.195	1.637	246.7
200.00	3.00	980	630.1	23.648	1.2822	.3818	413	.00020	3.796	271.2	18.482	1.707	257.3
300.00	2.00	896	598.1	23.648	1.2902	.3736	388	.00019	4.041	275.1	24.816	1.743	262.7
500.00	1.20	797	561.8	23.648	1.3005	.3637	357	.00017	4.363	279.5	35.998	1.782	268.6
800.00	.75	714	532.0	23.648	1.3097	.3554	329	.00015	4.675	282.9	50.700	1.814	273.4
1000.00	.60	677	519.0	23.648	1.3139	.3517	317	.00014	4.829	284.4	59.650	1.828	275.5
1500.00	.40	614	497.0	23.648	1.3216	.3453	301	.00014	5.120	287.0	80.136	1.851	278.9
R = 3.00, PERCENT FUEL = 19.13, O/F = 4.227													
1.00	600.00	2171	1024.7	25.337	1.1977	0.5023	728	0.00044					
1.05	571.43	2154	1016.4	25.342	1.1988	.4988	724	.00043	0.286	300.7	2.170	0.202	26.8
1.60	375.00	2008	947.7	25.377	1.2087	.4704	691	.00039	.900	165.4	1.010	.618	81.8
1.78	337.20	1972	931.2	25.385	1.2113	.4637	683	.00038	1.000	164.7	1.000	.681	90.2
2.00	300.00	1933	913.3	25.392	1.2143	.4565	674	.00037	1.101	165.3	1.009	.743	98.4
10.00	60.00	1426	702.8	25.435	1.2540	.3868	550	.00027	2.147	194.3	2.186	1.263	167.4
20.00	30.00	1235	630.9	25.437	1.2681	.3697	499	.00023	2.537	207.8	3.424	1.397	185.1
20.41	29.39	1230	628.9	25.437	1.2685	.3693	498	.00023	2.548	208.1	3.471	1.401	185.6
40.00	15.00	1064	568.7	25.438	1.2815	.3557	451	.00020	2.926	217.3	5.480	1.503	199.2
40.83	14.70	1059	567.0	25.438	1.2819	.3553	450	.00020	2.938	217.6	5.558	1.506	199.6
80.00	7.50	911	515.3	25.438	1.2945	.3434	406	.00018	3.325	225.2	8.881	1.589	210.5
100.00	6.00	866	499.8	25.438	1.2988	.3395	392	.00017	3.457	227.5	10.392	1.613	213.7
200.00	3.00	736	456.5	25.438	1.3124	.3282	350	.00015	3.880	233.6	16.984	1.678	222.3
300.00	2.00	668	434.3	25.438	1.3203	.3220	326	.00014	4.140	236.7	22.672	1.711	226.7
500.00	1.20	589	409.2	25.438	1.3301	.3148	297	.00012	4.484	240.1	32.650	1.746	231.4
800.00	.75	524	388.8	25.438	1.3385	.3089	272	.00011	4.819	242.8	45.684	1.775	235.2
1000.00	.60	495	379.9	25.438	1.3423	.3063	260	.00011	4.985	244.0	53.587	1.788	236.9
1500.00	.40	446	365.1	25.438	1.3491	.3019	242	.00010	5.298	245.9	71.604	1.808	239.6
R = 4.00, PERCENT FUEL = 15.07, O/F = 5.636													
1.00	600.00	1877	814.0	26.566	1.2276	0.4111	672	0.00034					
1.05	571.43	1861	807.1	26.568	1.2288	.4088	668	.00034	0.282	272.9	2.188	0.204	24.4
1.60	375.00	1719	750.8	26.581	1.2393	.3911	634	.00031	.891	149.5	1.011	.622	74.1
1.80	333.68	1680	735.9	26.584	1.2421	.3868	624	.00030	1.000	148.7	1.000	.691	82.4
2.00	300.00	1646	722.7	26.586	1.2446	.3831	616	.00029	1.092	149.2	1.007	.747	89.1
10.00	60.00	1179	553.9	26.596	1.2775	.3441	493	.00022	2.150	175.9	2.136	1.261	150.4
20.00	30.00	1012	497.3	26.596	1.2902	.3322	445	.00019	2.549	185.8	3.322	1.392	166.0
20.41	29.39	1007	495.7	26.596	1.2906	.3319	444	.00019	2.560	186.1	3.367	1.395	166.4
40.00	15.00	863	448.8	26.596	1.3028	.3215	399	.00017	2.948	194.0	5.280	1.494	178.2
40.83	14.70	859	447.5	26.596	1.3032	.3211	398	.00016	2.960	194.2	5.354	1.497	178.6
80.00	7.50	733	407.5	26.596	1.3162	.3110	356	.00014	3.358	200.7	8.497	1.577	188.0
100.00	6.00	694	395.7	26.596	1.3205	.3078	343	.00014	3.494	202.6	9.920	1.600	190.8
200.00	3.00	585	362.6	26.596	1.3341	.2983	305	.00012	3.934	207.8	16.099	1.662	198.2
300.00	2.00	528	345.7	26.596	1.3417	.2934	281	.00011	4.205	210.4	21.402	1.692	201.8
500.00	1.20	463	326.8	26.596	1.3509	.2877	254	.00010	4.565	213.2	30.665	1.726	205.9
800.00	.75	410	311.5	26.596	1.3580	.2834	231	.00009	4.917	215.5	42.718	1.753	209.1
1000.00	.60	386	304.9	26.596	1.3608	.2818	221	.00008	5.092	216.4	50.009	1.765	210.5
1500.00	.40	347	293.8	26.596	1.3650	.2794	203	.00008	5.425	218.0	66.614	1.784	212.7
R = 5.00, PERCENT FUEL = 12.43, O/F = 7.046													
1.00	600.00	1641	677.0	27.398	1.2506	0.3639	621	0.00028					
1.05	571.43	1625	671.3	27.399	1.2517	.3625	617	.00028	0.280	251.1	2.201	0.206	22.4
1.60	375.00	1491	623.7	27.403	1.2607	.3515	583	.00026	.885	137.2	1.013	.624	68.1
1.81	331.33	1454	610.5	27.404	1.2632	.3487	573	.00025	1.000	136.4	1.000	.698	76.1
2.00	300.00	1424	600.1	27.404	1.2652	.3465	566	.00025	1.085	136.7	1.006	.750	81.8
10.00	60.00	1001	459.7	27.406	1.2941	.3191	448	.00018	2.151	160.5	2.106	1.260	137.5
20.00	30.00	853	413.2	27.406	1.3065	.3091	402	.00016	2.555	169.3	3.257	1.389	151.5
20.41	29.39	849	411.9	27.406	1.3068	.3088	400	.00016	2.567	169.5	3.300	1.392	151.9
40.00	15.00	723	373.6	27.406	1.3197	.2993	358	.00014	2.961	176.5	5.149	1.489	162.5
40.83	14.70	720	372.5	27.406	1.3201	.2990	357	.00014	2.973	176.7	5.220	1.492	162.8
80.00	7.50	610	340.2	27.406	1.3335	.2900	317	.00012	3.380	182.4	8.240	1.569	171.2
100.00	6.00	577	330.6	27.406	1.3378	.2871	305	.00012	3.520	184.1	9.603	1.591	173.6
200.00	3.00	483	304.0	27.406	1.3509	.2792	267	.00010	3.972	188.6	15.498	1.651	180.2
300.00	2.00	434	290.5	27.406	1.3579	.2751	247	.00009	4.252	190.9	20.539	1.681	183.4
500.00	1.20	379	275.5	27.406	1.3649	.2712	222	.00008	4.626	193.3	29.324	1.713	186.9
800.00	.75	334	263.4	27.406	1.3697	.2687	201	.00007	4.993	195.3	40.741	1.739	189.7
1000.00	.60	315	258.1	27.406	1.3715	.2677	191	.00007	5.175	196.1	47.644	1.750	190.9
1500.00	.40	282	249.3	27.406	1.3739	.2664	175	.00006	5.520	197.5	63.255	1.768	192.9

TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 1500

FOR LIQUID AMMONIA WITH LIQUID OXYGEN

(d) Combustion-chamber pressure, 600 pounds per square inch absolute; frozen composition during isentropic expansion

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Molecular weight, $\mathcal{M}$	Isentropic exponent, γ	Specific heat, c_p, $\frac{cal}{(g)(^\circ K)}$	Absolute viscosity, μ, micropoises	Thermal conductivity, k, cal/(sec)(cm)(°K)	Mach number, M	Specific impulse, I_{vac}, $\frac{(lb)(sec)}{lb}$	Area ratio, ϵ	Thrust coefficient, C_F	Specific impulse, I, $\frac{(lb)(sec)}{lb}$
R = 0.40. PERCENT FUEL = 63.95. O/F = 0.564													
1.00	600.00	1349	3350.2	13.316	1.2956	0.6540	453	0.00038					
1.05	571.43	1334	3340.4	13.316	1.2966	.6524	450	.00038	0.275	326.2	2.226	0.208	29.1
1.60	375.00	1210	3260.5	13.316	1.3053	.6381	421	.00035	.872	177.3	1.015	.630	88.3
1.84	326.41	1171	3235.9	13.316	1.3082	.6335	412	.00034	1.000	176.0	1.000	.712	99.7
2.00	300.00	1148	3221.3	13.316	1.3100	.6307	406	.00033	1.072	176.3	1.004	.756	105.9
10.00	60.00	772	2993.1	13.316	1.3421	.5855	309	.00024	2.149	204.7	2.030	1.258	176.3
20.00	30.00	646	2919.9	13.316	1.3530	.5720	272	.00021	2.569	215.2	3.093	1.381	193.5
20.41	29.39	643	2917.9	13.316	1.3532	.5717	271	.00021	2.581	215.4	3.133	1.384	193.9
40.00	15.00	538	2858.8	13.316	1.3618	.5617	237	.00018	2.998	223.7	4.823	1.476	206.8
40.83	14.70	535	2857.1	13.316	1.3620	.5615	236	.00018	3.011	223.9	4.888	1.478	207.1
80.00	7.50	447	2807.9	13.316	1.3680	.5548	206	.00015	3.447	230.6	7.629	1.550	217.2
100.00	6.00	421	2793.5	13.316	1.3696	.5530	196	.00015	3.597	232.5	8.863	1.571	220.1
200.00	3.00	349	2753.8	13.316	1.3744	.5478	168	.00012	4.083	237.7	14.191	1.626	227.8
300.00	2.00	312	2733.8	13.316	1.3768	.5453	154	.00011	4.383	240.3	18.744	1.653	231.6
500.00	1.20	271	2711.6	13.316	1.3793	.5427	136	.00010	4.781	243.2	26.680	1.682	235.7
800.00	.75	238	2693.7	13.316	1.3842	.5377	122	.00009	5.163	245.5	36.978	1.705	239.0
1000.00	.60	224	2686.0	13.316	1.3871	.5348	115	.00008	5.351	246.4	43.187	1.715	240.4
1500.00	.40	200	2673.2	13.316	1.3927	.5293	104	.00007	5.707	248.0	57.266	1.732	242.7
R = 0.50. PERCENT FUEL = 58.67. O/F = 0.705													
1.00	600.00	1784	3075.9	14.516	1.2623	0.6588	555	0.00046					
1.05	571.43	1766	3064.0	14.516	1.2630	.6573	551	.00046	0.279	359.6	2.206	0.206	32.1
1.60	375.00	1617	2966.5	14.516	1.2697	.6444	520	.00042	.882	196.3	1.013	.626	97.5
1.82	330.40	1574	2938.9	14.516	1.2719	.6404	510	.00041	1.000	195.0	1.000	.700	109.2
2.00	300.00	1541	2918.3	14.516	1.2736	.6372	503	.00041	1.083	195.5	1.006	.751	117.1
10.00	60.00	1074	2632.5	14.516	1.3057	.5847	394	.00030	2.149	229.0	2.090	1.260	196.4
20.00	30.00	911	2538.4	14.516	1.3201	.5646	351	.00026	2.555	241.3	3.218	1.387	216.2
20.41	29.39	906	2535.9	14.516	1.3205	.5641	350	.00026	2.568	241.7	3.261	1.390	216.8
40.00	15.00	768	2459.0	14.516	1.3335	.5474	311	.00022	2.967	251.4	5.065	1.486	231.7
40.83	14.70	764	2456.8	14.516	1.3339	.5469	310	.00022	2.979	251.7	5.134	1.489	232.1
80.00	7.50	644	2392.1	14.516	1.3450	.5338	274	.00019	3.396	259.6	8.071	1.565	243.9
100.00	6.00	608	2373.0	14.516	1.3482	.5301	262	.00018	3.539	261.9	9.395	1.586	247.3
200.00	3.00	508	2320.2	14.516	1.3571	.5203	228	.00016	4.003	268.2	15.126	1.645	256.4
300.00	2.00	456	2293.5	14.516	1.3609	.5163	210	.00014	4.292	271.3	20.032	1.674	260.9
500.00	1.20	398	2263.7	14.516	1.3650	.5120	188	.00013	4.673	274.8	28.601	1.705	265.8
800.00	.75	351	2239.6	14.516	1.3683	.5086	169	.00012	5.045	277.5	39.755	1.730	269.8
1000.00	.60	330	2229.2	14.516	1.3696	.5073	161	.00011	5.228	278.7	46.505	1.741	271.4
1500.00	.40	296	2211.8	14.516	1.3717	.5053	146	.00010	5.575	280.6	61.881	1.759	274.2
R = 0.60. PERCENT FUEL = 54.19. O/F = 0.845													
1.00	600.00	2171	2843.5	15.710	1.2400	0.6536	640	0.00052					
1.05	571.43	2150	2830.1	15.710	1.2405	.6524	636	.00052	0.281	381.5	2.193	0.205	34.1
1.60	375.00	1980	2720.2	15.710	1.2455	.6417	602	.00048	.889	208.8	1.012	.623	103.6
1.80	333.20	1935	2690.9	15.710	1.2471	.6384	593	.00047	1.000	207.6	1.000	.693	115.2
2.00	300.00	1895	2665.5	15.710	1.2485	.6355	585	.00046	1.091	208.2	1.007	.748	124.5
10.00	60.00	1358	2336.7	15.710	1.2749	.5866	468	.00035	2.151	245.6	2.139	1.262	210.0
20.00	30.00	1166	2226.2	15.710	1.2887	.5647	421	.00030	2.548	259.4	3.329	1.393	231.8
20.41	29.39	1161	2223.2	15.710	1.2891	.5640	420	.00030	2.560	259.8	3.374	1.396	232.3
40.00	15.00	995	2131.6	15.710	1.3032	.5436	377	.00026	2.946	270.9	5.292	1.496	248.9
40.83	14.70	991	2129.0	15.710	1.3037	.5430	376	.00026	2.957	271.2	5.366	1.499	249.3
80.00	7.50	845	2051.1	15.710	1.3174	.5250	336	.00023	3.355	280.3	8.512	1.578	262.6
100.00	6.00	800	2027.8	15.710	1.3218	.5195	323	.00022	3.492	282.9	9.986	1.601	266.4
200.00	3.00	674	1963.3	15.710	1.3343	.5048	285	.00019	3.933	290.1	16.118	1.663	276.7
300.00	2.00	609	1930.5	15.710	1.3407	.4978	264	.00017	4.206	293.7	21.429	1.694	281.9
500.00	1.20	534	1893.6	15.710	1.3478	.4901	239	.00015	4.568	297.7	30.721	1.728	287.5
800.00	.75	473	1863.7	15.710	1.3533	.4845	217	.00014	4.921	300.9	42.837	1.755	292.0
1000.00	.60	446	1850.7	15.710	1.3554	.4824	207	.00013	5.096	302.3	50.179	1.766	293.9
1500.00	.40	401	1829.0	15.710	1.3589	.4789	189	.00012	5.427	304.5	66.923	1.786	297.1
R = 0.70. PERCENT FUEL = 50.34. O/F = 0.986													
1.00	600.00	2503	2644.0	16.876	1.2243	0.6428	711	0.00056					
1.05	571.43	2481	2629.7	16.876	1.2247	.6418	707	.00056	0.283	395.4	2.183	0.204	35.3
1.60	375.00	2295	2511.3	16.876	1.2287	.6326	671	.00052	.894	216.9	1.021	.620	107.5
1.79	335.17	2247	2481.3	16.876	1.2299	.6300	662	.00051	1.000	215.8	1.000	.687	119.0
2.00	300.00	2201	2452.3	16.876	1.2310	.6274	653	.00051	1.096	216.5	1.008	.746	129.2
10.00	60.00	1611	2093.3	16.876	1.2519	.5851	531	.00039	2.154	256.6	2.176	1.264	218.9
20.00	30.00	1398	1970.7	16.876	1.2638	.5641	482	.00034	2.545	271.6	3.415	1.397	242.1
20.41	29.39	1392	1967.3	16.876	1.2642	.5634	481	.00034	2.556	272.0	3.462	1.401	242.7
40.00	15.00	1206	1864.6	16.876	1.2770	.5428	436	.00030	2.932	284.2	5.478	1.504	260.4
40.83	14.70	1201	1861.7	16.876	1.2775	.5422	435	.00030	2.944	284.5	5.556	1.506	260.9
80.00	7.50	1034	1773.3	16.876	1.2914	.5218	392	.00026	3.327	294.5	8.892	1.589	275.3
100.00	6.00	983	1746.8	16.876	1.2961	.5155	378	.00025	3.458	297.4	10.408	1.613	279.4
200.00	3.00	837	1672.6	16.876	1.3104	.4971	337	.00022	3.879	305.5	17.027	1.679	290.7
300.00	2.00	759	1634.5	16.876	1.3184	.4876	314	.00020	4.138	309.5	22.738	1.711	296.4
500.00	1.20	670	1591.6	16.876	1.3276	.4772	286	.00018	4.482	314.0	32.762	1.747	302.6
800.00	.75	596	1556.6	16.876	1.3352	.4690	262	.00016	4.816	317.5	45.874	1.776	307.6
1000.00	.60	564	1541.3	16.876	1.3386	.4655	250	.00015	4.982	319.1	53.831	1.788	309.8
1500.00	.40	508	1515.7	16.876	1.3441	.4599	231	.00014	5.295	321.6	71.999	1.809	313.3

TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 1500

FOR LIQUID AMMONIA WITH LIQUID OXYGEN

(d) Continued. Combustion-chamber pressure, 600 pounds per square inch absolute; frozen composition during isentropic expansion

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Molecular weight, $\mathcal{M}$	Isentropic exponent, γ	Specific heat, c_p, $\frac{cal}{(g)(^{\circ}K)}$	Absolute viscosity, μ, micropoises	Thermal conductivity, k, $\frac{cal}{(sec)(cm)(^{\circ}K)}$	Mach number, M	Specific impulse, I_{vac}, $\frac{(lb)(sec)}{lb}$	Area ratio, ε	Thrust coefficient, C_F	Specific impulse, I, $\frac{(lb)(sec)}{lb}$
R = 0.80, PERCENT FUEL = 47.01, O/F = 1.127													
1.00	600.00	2760	2471.0	17.957	1.2139	0.6281	767	0.00059					
1.05	571.43	2737	2456.2	17.957	1.2142	.6272	762	.00058	0.284	402.6	2.176	0.203	35.9
1.60	375.00	2539	2333.3	17.957	1.2174	.6196	726	.00055	.897	221.2	1.010	.619	109.5
1.78	336.51	2491	2303.1	17.957	1.2183	.6176	717	.00054	1.000	220.1	1.000	.683	120.9
2.00	300.00	2440	2271.8	17.957	1.2193	.6153	707	.00053	1.100	220.9	1.009	.744	131.7
10.00	60.00	1811	1895.5	17.957	1.2368	.5781	581	.00042	2.155	262.7	2.202	1.265	223.8
20.00	30.00	1582	1765.5	17.957	1.2466	.5593	551	.00037	2.542	278.5	3.476	1.401	247.8
20.41	29.39	1576	1761.9	17.957	1.2470	.5588	529	.00037	2.554	278.9	3.525	1.404	248.4
40.00	15.00	1376	1652.2	17.957	1.2584	.5389	483	.00033	2.923	291.7	5.612	1.509	266.9
40.83	14.70	1370	1649.1	17.957	1.2588	.5383	481	.00033	2.935	292.1	5.693	1.512	267.4
80.00	7.50	1190	1553.9	17.957	1.2715	.5183	437	.00029	3.310	302.8	9.173	1.597	282.5
100.00	6.00	1134	1525.2	17.957	1.2760	.5116	422	.00027	3.436	305.9	10.762	1.622	286.9
200.00	3.00	973	1444.5	17.957	1.2904	.4917	379	.00024	3.843	314.6	17.730	1.690	298.9
300.00	2.00	888	1402.7	17.957	1.2989	.4809	355	.00022	4.092	318.9	23.773	1.724	304.9
500.00	1.20	788	1355.4	17.957	1.3093	.4684	325	.00020	4.421	323.7	34.418	1.761	311.6
800.00	.75	704	1316.6	17.957	1.3183	.4583	300	.00018	4.740	327.6	48.386	1.792	316.9
1000.00	.60	667	1299.7	17.957	1.3223	.4540	288	.00017	4.899	329.3	56.880	1.805	319.2
1500.00	.40	604	1271.2	17.957	1.3291	.4469	266	.00016	5.198	332.1	76.307	1.827	323.1
R = 0.90, PERCENT FUEL = 44.09, O/F = 1.268													
1.00	600.00	2922	2319.5	18.893	1.2077	0.6116	805	0.00060					
1.05	571.43	2897	2304.6	18.893	1.2080	.6108	801	.00059	0.285	403.8	2.173	0.203	36.0
1.60	375.00	2693	2180.8	18.893	1.2110	.6038	764	.00056	.899	222.0	1.010	.618	109.9
1.78	337.27	2644	2151.0	18.893	1.2117	.6019	755	.00055	1.000	221.0	1.000	.681	121.1
2.00	300.00	2590	2118.8	18.893	1.2126	.5999	745	.00054	1.102	221.8	1.009	.743	132.2
10.00	60.00	1938	1737.6	18.893	1.2279	.5667	615	.00043	2.156	264.4	2.218	1.266	225.0
20.00	30.00	1701	1605.1	18.893	1.2369	.5492	564	.00038	2.541	280.5	3.513	1.403	249.3
20.41	29.39	1694	1601.4	18.893	1.2372	.5487	563	.00038	2.552	281.0	3.562	1.406	250.0
40.00	15.00	1486	1489.0	18.893	1.2473	.5304	515	.00034	2.919	294.1	5.693	1.512	268.8
40.83	14.70	1480	1485.8	18.893	1.2477	.5298	513	.00034	2.930	294.5	5.776	1.515	269.3
80.00	7.50	1292	1387.9	18.893	1.2595	.5105	465	.00030	3.300	305.5	9.345	1.602	284.7
100.00	6.00	1234	1358.3	18.893	1.2637	.5041	449	.00029	3.424	308.7	10.979	1.627	289.2
200.00	3.00	1064	1274.6	18.893	1.2777	.4840	396	.00024	3.823	317.7	18.171	1.696	301.5
300.00	2.00	973	1231.2	18.893	1.2861	.4728	364	.00022	4.066	322.2	24.429	1.731	307.7
500.00	1.20	867	1181.8	18.893	1.2967	.4596	325	.00019	4.386	327.3	35.486	1.770	314.6
800.00	.75	778	1141.1	18.893	1.3063	.4485	295	.00017	4.696	331.3	50.034	1.801	320.2
1000.00	.60	738	1123.3	18.893	1.3107	.4437	281	.00016	4.849	333.1	58.894	1.815	322.6
1500.00	.40	670	1093.3	18.893	1.3182	.4357	257	.00015	5.139	336.0	79.187	1.838	326.6
R = 0.95, PERCENT FUEL = 42.76, O/F = 1.339													
1.00	600.00	2963	2250.6	19.291	1.2061	0.6028	818	0.00060					
1.05	571.43	2939	2235.8	19.291	1.2064	.6021	814	.00059	0.285	402.6	2.172	0.203	35.9
1.60	375.00	2733	2112.8	19.291	1.2093	.5953	776	.00056	.900	221.4	1.010	.618	109.5
1.78	337.47	2684	2083.3	19.291	1.2100	.5935	767	.00055	1.000	220.3	1.000	.681	120.6
2.00	300.00	2630	2051.1	19.291	1.2109	.5915	757	.00054	1.103	221.2	1.009	.743	131.7
10.00	60.00	1972	1671.8	19.291	1.2256	.5596	626	.00043	2.156	263.8	2.222	1.266	224.4
20.00	30.00	1732	1539.7	19.291	1.2343	.5426	574	.00039	2.541	279.9	3.522	1.403	248.7
20.41	29.39	1726	1536.0	19.291	1.2346	.5421	573	.00038	2.552	280.4	3.572	1.407	249.4
40.00	15.00	1516	1423.9	19.291	1.2444	.5244	525	.00034	2.917	293.5	5.714	1.513	268.2
40.83	14.70	1509	1420.7	19.291	1.2448	.5239	523	.00034	2.929	293.9	5.798	1.516	268.7
80.00	7.50	1319	1322.8	19.291	1.2564	.5048	477	.00030	3.297	304.9	9.390	1.603	284.1
100.00	6.00	1260	1293.1	19.291	1.2604	.4985	463	.00029	3.421	308.2	11.037	1.628	288.6
200.00	3.00	1089	1209.4	19.291	1.2742	.4787	418	.00025	3.817	317.2	18.290	1.698	301.0
300.00	2.00	997	1165.9	19.291	1.2826	.4675	392	.00023	4.059	321.8	24.607	1.733	307.2
500.00	1.20	889	1116.3	19.291	1.2932	.4543	362	.00021	4.376	326.9	35.778	1.772	314.2
800.00	.75	798	1075.5	19.291	1.3029	.4431	334	.00019	4.684	331.0	50.487	1.804	319.8
1000.00	.60	758	1057.6	19.291	1.3073	.4382	322	.00018	4.836	332.7	59.451	1.818	322.2
1500.00	.40	688	1027.4	19.291	1.3150	.4300	299	.00017	5.123	335.7	79.988	1.840	326.2
R = 0.975, PERCENT FUEL = 42.13, O/F = 1.374													
1.00	600.00	2975	2217.7	19.471	1.2056	0.5984	823	0.00060					
1.05	571.43	2950	2202.9	19.471	1.2059	.5977	818	.00059	0.285	401.5	2.171	0.203	35.8
1.60	375.00	2744	2080.6	19.471	1.2088	.5909	780	.00056	.900	220.8	1.010	.618	109.2
1.78	337.53	2695	2051.4	19.471	1.2095	.5892	771	.00055	1.000	219.8	1.000	.680	120.5
2.00	300.00	2640	2019.3	19.471	1.2104	.5872	761	.00054	1.103	220.6	1.009	.743	131.4
10.00	60.00	1981	1641.8	19.471	1.2249	.5558	630	.00043	2.156	263.2	2.223	1.266	223.9
20.00	30.00	1741	1510.3	19.471	1.2336	.5390	578	.00039	2.541	279.3	3.525	1.403	248.1
20.41	29.39	1734	1506.6	19.471	1.2338	.5385	577	.00038	2.552	279.7	3.575	1.407	248.7
40.00	15.00	1524	1394.9	19.471	1.2436	.5211	528	.00034	2.917	292.9	5.720	1.513	267.6
40.83	14.70	1518	1391.7	19.471	1.2439	.5205	527	.00034	2.928	293.2	5.804	1.516	268.1
80.00	7.50	1327	1294.2	19.471	1.2554	.5016	481	.00030	3.296	304.3	9.404	1.603	283.5
100.00	6.00	1268	1264.7	19.471	1.2595	.4954	466	.00029	3.420	307.5	11.054	1.629	288.0
200.00	3.00	1096	1181.2	19.471	1.2731	.4757	421	.00025	3.816	316.5	18.325	1.699	300.3
300.00	2.00	1003	1137.8	19.471	1.2815	.4646	395	.00023	4.057	321.1	24.660	1.734	306.5
500.00	1.20	895	1088.3	19.471	1.2922	.4514	364	.00021	4.374	326.2	35.865	1.773	313.5
800.00	.75	804	1047.6	19.471	1.3019	.4402	337	.00019	4.680	330.3	50.623	1.805	319.1
1000.00	.60	763	1029.7	19.471	1.3063	.4352	324	.00018	4.832	332.0	59.618	1.818	321.5
1500.00	.40	693	999.6	19.471	1.3141	.4270	302	.00017	5.118	335.0	80.230	1.841	325.6

TABLE II. - Continued. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 1500 FOR LIQUID AMMONIA WITH LIQUID OXYGEN

(d) Continued. Combustion-chamber pressure, 600 pounds per square inch absolute; frozen composition during isentropic expansion

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Molecular weight, $\mathcal{M}$	Isentropic exponent, γ	Specific heat, c_p, $\frac{cal}{(g)(^\circ K)}$	Absolute viscosity, μ, micropoises	Thermal conductivity, k, cal/(sec)(cm)(°K)	Mach number, M	Specific impulse, I_{vac}, $\frac{(lb)(sec)}{lb}$	Area ratio, ϵ	Thrust coefficient, C_F	Specific impulse, I, $\frac{(lb)(sec)}{lb}$
R = 1.00, PERCENT FUEL = 41.51, O/F = 1.409													
1.00	600.00	2980	2185.7	19.638	1.2054	0.5939	826	0.00060					
1.05	571.43	2956	2171.1	19.638	1.2057	.5932	821	.00059	0.285	400.1	2.171	0.203	35.7
1.60	375.00	2750	2049.5	19.636	1.2085	.5866	784	.00056	.900	220.1	1.010	.618	108.9
1.78	337.56	2700	2020.5	19.638	1.2092	.5848	774	.00055	1.000	219.0	1.000	.680	119.9
2.00	300.00	2646	1988.6	19.638	1.2101	.5829	764	.00054	1.103	219.9	1.009	.743	131.0
10.00	60.00	1986	1613.5	19.638	1.2246	.5518	633	.00043	2.156	262.3	2.223	1.266	223.1
20.00	30.00	1746	1482.8	19.638	1.2331	.5352	581	.00038	2.540	278.4	3.527	1.403	247.3
20.41	29.39	1739	1479.2	19.638	1.2334	.5347	579	.00038	2.552	278.8	3.576	1.407	247.9
40.00	15.00	1528	1368.1	19.638	1.2431	.5175	531	.00034	2.917	291.9	5.724	1.513	266.7
40.83	14.70	1522	1365.0	19.638	1.2434	.5169	530	.00034	2.928	292.3	5.808	1.516	267.2
80.00	7.50	1331	1268.0	19.638	1.2549	.4982	482	.00030	3.296	303.3	9.411	1.603	282.6
100.00	6.00	1271	1238.6	19.638	1.2589	.4920	465	.00029	3.420	306.6	11.064	1.629	287.1
200.00	3.00	1099	1155.6	19.638	1.2725	.4725	412	.00025	3.815	315.6	18.345	1.699	299.4
300.00	2.00	1007	1112.4	19.638	1.2809	.4614	381	.00022	4.056	320.1	24.691	1.734	305.6
500.00	1.20	899	1063.2	19.638	1.2915	.4483	341	.00020	4.372	325.2	35.916	1.773	312.5
800.00	.75	807	1022.7	19.638	1.3012	.4371	308	.00017	4.678	329.3	50.704	1.805	318.1
1000.00	.60	766	1004.9	19.638	1.3057	.4322	294	.00016	4.830	331.1	59.717	1.819	320.5
1500.00	.40	696	974.9	19.638	1.3135	.4240	270	.00015	5.116	334.0	80.374	1.842	324.6
R = 1.10, PERCENT FUEL = 39.22, O/F = 1.550													
1.00	600.00	2962	2066.7	20.207	1.2057	0.5764	831	0.00058					
1.05	571.43	2937	2052.6	20.207	1.2060	.5757	827	.00058	0.285	393.2	2.171	0.203	35.1
1.60	375.00	2732	1935.2	20.207	1.2088	.5692	789	.00055	.900	216.3	1.010	.628	107.0
1.78	337.52	2683	1907.2	20.207	1.2096	.5676	779	.00054	1.000	215.2	1.000	.680	117.8
2.00	300.00	2629	1876.4	20.207	1.2104	.5657	769	.00053	1.103	216.1	1.009	.743	128.7
10.00	60.00	1972	1514.3	20.207	1.2250	.5354	637	.00042	2.156	257.7	2.223	1.266	219.3
20.00	30.00	1733	1388.1	20.207	1.2336	.5193	584	.00038	2.541	273.5	3.525	1.403	243.0
20.41	29.39	1727	1384.6	20.207	1.2339	.5188	583	.00037	2.552	273.9	3.574	1.407	243.6
40.00	15.00	1517	1277.5	20.207	1.2436	.5021	534	.00033	2.917	286.8	5.720	1.513	262.1
40.83	14.70	1511	1274.4	20.207	1.2439	.5016	532	.00033	2.928	287.2	5.804	1.516	262.6
80.00	7.50	1321	1180.9	20.207	1.2553	.4835	484	.00029	3.296	298.0	9.403	1.603	277.6
100.00	6.00	1262	1152.5	20.207	1.2594	.4775	468	.00028	3.421	301.2	11.054	1.629	282.0
200.00	3.00	1091	1072.4	20.207	1.2730	.4586	414	.00024	3.816	310.0	18.325	1.699	294.1
300.00	2.00	999	1030.8	20.207	1.2813	.4480	382	.00022	4.057	314.5	24.661	1.734	300.2
500.00	1.20	892	983.3	20.207	1.2919	.4353	342	.00019	4.374	319.5	35.870	1.773	307.0
800.00	.75	801	944.3	20.207	1.3015	.4245	310	.00017	4.680	323.5	50.634	1.805	312.5
1000.00	.60	760	927.2	20.207	1.3060	.4197	296	.00016	4.832	325.2	59.633	1.818	314.9
1500.00	.40	691	898.2	20.207	1.3137	.4118	272	.00015	5.118	328.1	80.257	1.841	318.9
R = 1.20, PERCENT FUEL = 37.16, O/F = 1.691													
1.00	600.00	2914	1960.2	20.677	1.2071	0.5602	829	0.00056					
1.05	571.43	2890	1946.6	20.677	1.2074	.5594	825	.00056	0.285	385.6	2.172	0.203	34.4
1.60	375.00	2687	1833.7	20.677	1.2103	.5531	787	.00053	.900	212.0	1.010	.618	104.9
1.78	337.35	2638	1806.7	20.677	1.2111	.5514	777	.00052	1.000	211.0	1.000	.681	115.6
2.00	300.00	2585	1777.2	20.677	1.2119	.5496	767	.00051	1.103	211.8	1.009	.743	126.2
10.00	60.00	1936	1429.6	20.677	1.2269	.5196	634	.00041	2.156	252.5	2.219	1.266	214.9
20.00	30.00	1700	1308.6	20.677	1.2357	.5039	581	.00036	2.541	268.0	3.517	1.403	238.1
20.41	29.39	1693	1305.3	20.677	1.2359	.5034	580	.00036	2.552	268.4	3.566	1.406	238.7
40.00	15.00	1486	1202.6	20.677	1.2459	.4870	531	.00032	2.918	280.9	5.702	1.513	256.7
40.83	14.70	1480	1199.7	20.677	1.2462	.4865	530	.00032	2.929	281.3	5.786	1.515	257.2
80.00	7.50	1293	1110.2	20.677	1.2577	.4690	483	.00028	3.299	291.8	9.366	1.602	272.0
100.00	6.00	1234	1083.1	20.677	1.2618	.4632	468	.00027	3.423	294.9	11.007	1.628	276.3
200.00	3.00	1066	1006.6	20.677	1.2755	.4450	422	.00024	3.821	303.5	18.231	1.697	288.1
300.00	2.00	976	966.8	20.677	1.2837	.4348	397	.00022	4.063	307.9	24.522	1.732	294.0
500.00	1.20	870	921.5	20.677	1.2943	.4227	366	.00020	4.381	312.7	35.644	1.771	300.6
800.00	.75	781	884.3	20.677	1.3039	.4124	338	.00018	4.690	316.6	50.287	1.803	306.0
1000.00	.60	741	868.0	20.677	1.3082	.4079	325	.00017	4.842	318.3	59.209	1.816	308.3
1500.00	.40	673	840.4	20.677	1.3159	.4004	302	.00016	5.130	321.2	79.651	1.839	312.1
R = 1.50, PERCENT FUEL = 32.12, O/F = 2.114													
1.00	600.00	2759	1698.4	21.847	1.2121	0.5198	815	0.00052					
1.05	571.43	2736	1686.2	21.847	1.2124	.5191	810	.00051	0.284	365.0	2.175	0.203	32.6
1.60	375.00	2540	1585.2	21.847	1.2155	.5130	772	.00048	.898	200.5	1.010	.619	99.3
1.78	336.73	2492	1560.6	21.847	1.2164	.5114	762	.00048	1.000	199.6	1.000	.685	109.5
2.00	300.00	2441	1534.7	21.847	1.2173	.5096	752	.00047	1.101	200.3	1.009	.744	119.4
10.00	60.00	1817	1224.8	21.847	1.2338	.4800	619	.00037	2.156	238.4	2.207	1.265	203.0
20.00	30.00	1590	1117.5	21.847	1.2430	.4654	566	.00033	2.542	252.8	3.488	1.401	224.8
20.41	29.39	1583	1114.6	21.847	1.2433	.4649	565	.00033	2.554	253.2	3.537	1.405	225.4
40.00	15.00	1385	1023.8	21.847	1.2539	.4492	516	.00029	2.922	264.9	5.640	1.510	242.3
40.83	14.70	1379	1021.3	21.847	1.2542	.4487	514	.00029	2.934	265.2	5.722	1.513	242.7
80.00	7.50	1201	942.4	21.847	1.2660	.4329	468	.00026	3.307	275.0	9.236	1.599	256.5
100.00	6.00	1145	918.6	21.847	1.2703	.4275	455	.00025	3.433	277.9	10.844	1.624	260.5
200.00	3.00	985	851.6	21.847	1.2840	.4113	408	.00021	3.836	285.8	17.905	1.692	271.5
300.00	2.00	900	816.8	21.847	1.2922	.4023	382	.00020	4.083	289.8	24.041	1.726	277.0
500.00	1.20	800	777.4	21.847	1.3025	.3916	352	.00018	4.407	294.3	34.870	1.764	283.1
800.00	.75	717	745.0	21.847	1.3117	.3828	324	.00016	4.722	297.9	49.102	1.795	288.0
1000.00	.60	680	730.8	21.847	1.3159	.3789	312	.00015	4.878	299.4	57.764	1.809	290.2
1500.00	.40	616	706.9	21.847	1.3233	.3723	289	.00014	5.172	302.0	77.590	1.831	293.7

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TABLE II. - Concluded. THEORETICAL ROCKET PERFORMANCE AT ASSIGNED PRESSURE RATIOS FROM 1 TO 1500 FOR LIQUID AMMONIA WITH LIQUID OXYGEN

(d) Concluded. Combustion-chamber pressure, 600 pounds per square inch absolute; frozen composition during isentropic expansion

Pressure ratio, P_c/P	Static pressure, P, lb/sq in. abs	Temperature, T, °K	Enthalpy, h, cal/g	Molecular weight, $\mathscr{M}$	Isentropic exponent, Γ	Specific heat, c_p, $\frac{cal}{(g)(^{\circ}K)}$	Absolute viscosity, μ, micropoises	Thermal conductivity, k, cal/(sec)(cm)(°K)	Mach number, M	Specific impulse, I_{vac}, $\frac{(lb)(sec)}{lb}$	Area ratio, ε	Thrust coefficient, C_F	Specific impulse, I, $\frac{(lb)(sec)}{lb}$
R = 2.00, PERCENT FUEL = 26.19, O/F = 2.818													
1.00	600.00	2536	1391.0	23.349	1.2200	0.4720	786	0.00045					
1.05	571.43	2513	1380.5	23.349	1.2204	.4713	782	.00045	0.283	338.3	2.180	0.204	30.2
1.60	375.00	2328	1293.7	23.349	1.2240	.4651	744	.00043	.895	185.7	1.010	.620	92.0
1.79	335.73	2281	1272.0	23.349	1.2250	.4633	734	.00042	1.000	184.8	1.000	.685	101.7
2.00	300.00	2235	1250.4	23.349	1.2261	.4615	724	.00041	1.098	185.4	1.008	.745	110.6
10.00	60.00	1646	986.3	23.349	1.2444	.4334	591	.00032	2.155	220.1	2.188	1.264	187.7
20.00	30.00	1433	895.6	23.349	1.2545	.4195	539	.00028	2.545	233.2	3.444	1.399	207.6
20.41	29.39	1427	893.1	23.349	1.2548	.4191	537	.00028	2.556	233.5	3.492	1.402	208.1
40.00	15.00	1242	816.8	23.349	1.2659	.4052	489	.00025	2.929	244.1	5.546	1.506	223.5
40.83	14.70	1237	814.6	23.349	1.2662	.4048	488	.00025	2.941	244.4	5.626	1.509	223.9
80.00	7.50	1071	748.6	23.349	1.2786	.3906	442	.00022	3.320	253.2	9.042	1.593	236.4
100.00	6.00	1020	728.8	23.349	1.2829	.3860	427	.00021	3.449	255.8	10.600	1.617	240.0
200.00	3.00	873	673.1	23.349	1.2964	.3723	383	.00018	3.861	262.9	17.426	1.684	249.9
300.00	2.00	795	644.3	23.349	1.3045	.3646	359	.00017	4.114	266.4	23.338	1.718	254.9
500.00	1.20	704	611.7	23.349	1.3144	.3558	329	.00015	4.447	270.4	33.746	1.755	260.4
800.00	.75	629	585.1	23.349	1.3232	.3484	302	.00014	4.771	273.6	47.391	1.784	264.8
1000.00	.60	595	573.5	23.349	1.3272	.3452	290	.00013	4.931	275.0	55.682	1.797	266.7
1500.00	.40	538	553.9	23.349	1.3341	.3398	268	.00012	5.234	277.3	74.630	1.818	269.9
R = 3.00, PERCENT FUEL = 19.13, O/F = 4.227													
1.00	600.00	2171	1024.7	25.337	1.2350	0.4122	728	0.00037					
1.05	571.43	2151	1016.4	25.337	1.2355	.4115	724	.00037	0.282	300.4	2.189	0.204	26.8
1.60	375.00	1984	948.2	25.337	1.2398	.4056	686	.00035	.891	164.6	1.011	.622	81.6
1.80	333.89	1940	930.3	25.337	1.2410	.4038	676	.00034	1.000	163.7	1.000	.691	90.6
2.00	300.00	1900	914.2	25.337	1.2423	.4022	667	.00033	1.093	164.2	1.007	.747	98.1
10.00	60.00	1373	709.0	25.337	1.2636	.3760	537	.00025	2.154	194.0	2.155	1.263	165.7
20.00	30.00	1186	639.6	25.337	1.2745	.3641	487	.00022	2.549	205.2	3.369	1.395	183.1
20.41	29.39	1181	637.7	25.337	1.2749	.3638	485	.00022	2.561	205.5	3.415	1.398	183.5
40.00	15.00	1019	579.7	25.337	1.2868	.3519	439	.00020	2.942	214.4	5.385	1.499	196.8
40.83	14.70	1014	578.1	25.337	1.2872	.3515	438	.00020	2.954	214.7	5.461	1.502	197.1
80.00	7.50	871	528.5	25.337	1.2997	.3402	394	.00017	3.344	222.1	8.715	1.583	207.8
100.00	6.00	827	513.6	25.337	1.3040	.3364	380	.00017	3.477	224.3	10.193	1.607	210.9
200.00	3.00	701	472.1	25.337	1.3174	.3255	339	.00014	3.905	230.2	16.636	1.671	219.3
300.00	2.00	636	450.9	25.337	1.3253	.3195	315	.00013	4.168	233.1	22.188	1.703	223.4
500.00	1.20	560	427.0	25.337	1.3348	.3127	287	.00012	4.516	236.4	31.918	1.738	228.1
800.00	.75	497	407.5	25.337	1.3429	.3072	262	.00011	4.856	239.1	44.621	1.766	231.7
1000.00	.60	469	399.1	25.337	1.3468	.3046	251	.00010	5.023	240.2	52.316	1.778	233.3
1500.00	.40	423	384.9	25.337	1.3528	.3007	231	.00009	5.342	242.1	69.858	1.798	235.9
R = 4.00, PERCENT FUEL = 15.07, O/F = 5.636													
1.00	600.00	1877	814.0	26.566	1.2487	0.3755	672	0.00032					
1.05	571.43	1859	807.1	26.566	1.2493	.3748	668	.00031	0.280	272.8	2.197	0.205	24.4
1.60	375.00	1708	751.0	26.566	1.2543	.3689	631	.00029	.887	149.1	1.012	.624	74.0
1.81	332.23	1667	735.7	26.566	1.2557	.3673	621	.00029	1.000	148.3	1.000	.695	82.5
2.00	300.00	1632	723.1	26.566	1.2570	.3659	613	.00028	1.088	148.7	1.007	.749	88.9
10.00	60.00	1162	556.2	26.566	1.2802	.3418	488	.00021	2.153	175.0	2.127	1.262	149.8
20.00	30.00	996	500.3	26.566	1.2921	.3309	441	.00019	2.553	184.8	3.305	1.392	165.2
20.41	29.39	991	498.8	26.566	1.2924	.3306	439	.00019	2.565	185.1	3.350	1.395	165.6
40.00	15.00	849	452.6	26.566	1.3046	.3204	395	.00016	2.953	192.9	5.252	1.494	177.3
40.83	14.70	845	451.3	26.566	1.3050	.3201	394	.00016	2.965	193.1	5.325	1.497	177.6
80.00	7.50	720	412.0	26.566	1.3180	.3101	352	.00014	3.365	199.6	8.448	1.576	187.0
100.00	6.00	682	400.3	26.566	1.3223	.3069	339	.00014	3.501	201.4	9.861	1.598	189.7
200.00	3.00	575	367.8	26.566	1.3358	.2976	299	.00012	3.942	206.5	15.994	1.660	197.0
300.00	2.00	519	351.2	26.566	1.3432	.2927	277	.00011	4.215	209.1	21.257	1.691	200.7
500.00	1.20	455	332.6	26.566	1.3524	.2871	251	.00010	4.576	211.9	30.448	1.724	204.6
800.00	.75	402	317.6	26.566	1.3592	.2831	228	.00009	4.930	214.1	42.406	1.751	207.8
1000.00	.60	379	311.1	26.566	1.3618	.2815	218	.00008	5.106	215.1	49.639	1.762	209.2
1500.00	.40	340	300.2	26.566	1.3658	.2795	199	.00007	5.440	216.7	66.112	1.781	211.4
R = 5.00, PERCENT FUEL = 12.43, O/F = 7.046													
1.00	600.00	1641	677.0	27.398	1.2610	0.3504	621	0.00027					
1.05	571.43	1624	671.3	27.398	1.2616	.3498	617	.00027	0.279	251.0	2.205	0.206	22.4
1.60	375.00	1487	623.7	27.398	1.2670	.3441	582	.00025	.883	137.0	1.013	.625	68.1
1.81	330.77	1449	610.4	27.398	1.2687	.3424	572	.00025	1.000	136.2	1.000	.699	76.2
2.00	300.00	1419	600.2	27.398	1.2701	.3411	564	.00024	1.084	136.5	1.006	.751	81.7
10.00	60.00	996	460.5	27.398	1.2948	.3185	446	.00018	2.152	160.2	2.103	1.261	137.3
20.00	30.00	848	414.2	27.398	1.3071	.3087	400	.00016	2.557	168.9	3.252	1.389	151.2
20.41	29.39	844	412.9	27.398	1.3075	.3084	399	.00016	2.568	169.2	3.295	1.392	151.6
40.00	15.00	719	374.9	27.398	1.3203	.2990	357	.00014	2.963	176.1	5.140	1.489	162.2
40.83	14.70	715	373.8	27.398	1.3207	.2987	355	.00014	2.975	176.3	5.212	1.492	162.4
80.00	7.50	606	341.6	27.398	1.3340	.2897	316	.00012	3.382	182.0	8.226	1.569	170.8
100.00	6.00	573	332.1	27.398	1.3384	.2869	303	.00011	3.522	183.7	9.585	1.591	173.3
200.00	3.00	480	305.7	27.398	1.3514	.2789	266	.00010	3.975	188.2	15.468	1.651	179.8
300.00	2.00	431	292.3	27.398	1.3584	.2749	245	.00009	4.255	190.4	20.497	1.681	183.0
500.00	1.20	377	277.3	27.398	1.3652	.2711	221	.00008	4.630	192.9	29.262	1.713	186.5
800.00	.75	332	265.3	27.398	1.3699	.2686	200	.00007	4.997	194.8	40.653	1.739	189.3
1000.00	.60	312	260.1	27.398	1.3717	.2677	190	.00007	5.180	195.7	47.540	1.749	190.5
1500.00	.40	280	251.4	27.398	1.3741	.2664	174	.00006	5.525	197.0	63.216	1.768	192.5

TABLE III. - THERMODYNAMIC DERIVATIVES AT ASSIGNED PRESSURE RATIOS FOR LIQUID AMMONIA AND LIQUID OXYGEN

(a) Chamber pressure, 300 pounds per square inch absolute; equilibrium composition during isentropic expansion

Pressure ratio, P_c/P	Temperature, T, °K	Temperature exponent, n_T	Area ratio, ϵ	Area-ratio exponent, n_ϵ	Specific impulse, I, $\frac{(lb)(sec)}{lb}$	Specific-impulse exponent, n_I	Specific heat, c_p, $(\partial h/\partial T)_p$, (cal)/(g)(°K)	$\left(\frac{\partial \ln \mathcal{M}}{\partial \ln P}\right)_T$	$\left(\frac{\partial \ln \mathcal{M}}{\partial \ln T}\right)_p$
R, 0.40; percent fuel, 63.95; O/F, 0.564									
1.00	1349	0.0000					0.6541	0.00000	0.0000
1.05	1334	.0000	2.226	0.0000	29.1	0.0000	.6524	.00000	.0000
1.60	1210	.0000	1.015	.0000	88.3	.0000	.6381	.00000	.0000
1.84	1171	.0000	1.000	.0000	99.7	.0000	.6335	.00000	.0000
2.00	1148	.0000	1.004	.0000	105.9	.0000	.6306	.00000	.0000
10.00	772	.0000	2.030	.0000	176.3	.0000	.5855	.00000	.0000
20.00	646	.0000	3.093	.0000	193.5	.0000	.5720	.00000	.0000
20.41	643	.0000	3.133	.0000	193.9	.0000	.5718	.00000	.0000
40.00	538	.0000	4.823	.0000	206.8	.0000	.5617	.00000	.0000
40.83	535	.0000	4.888	.0000	207.1	.0000	.5614	.00000	.0000
80.00	447	.0000	7.629	.0000	217.2	.0000	.5547	.00000	.0000
100.00	421	.0000	8.863	.0000	220.1	.0000	.5530	.00000	.0000
200.00	349	.0000	14.191	.0000	227.8	.0000	.5479	.00000	.0000
300.00	312	.0000	18.744	.0000	231.6	.0000	.5454	.00000	.0000
500.00	271	.0000	26.680	.0000	235.7	.0000	.5429	.00000	.0000
800.00	238	.0000	36.978	.0000	239.0	.0000	.5377	.00000	.0000
1000.00	224	.0000	43.187	.0000	240.4	.0000	.5347	.00000	.0000
1500.00	200	.0000	57.266	.0000	242.7	.0000	.5291	.00000	.0000
R, 0.50; percent fuel, 58.67; O/F, 0.705									
1.00	1784	0.0001					0.6607	0.00001	-.0004
1.05	1766	.0001	2.206	0.0000	32.1	0.0000	.6590	.00001	-.0004
1.60	1617	.0000	1.013	.0000	97.5	.0000	.6450	.00000	-.0001
1.82	1574	.0000	1.000	.0000	109.2	.0000	.6408	.00000	-.0001
2.00	1542	.0000	1.006	.0000	117.1	.0000	.6375	.00000	-.0001
10.00	1075	.0000	2.090	.0000	196.4	.0000	.5847	.00000	.0000
20.00	911	.0000	3.218	.0000	216.3	.0000	.5647	.00000	.0000
20.41	906	.0000	3.261	.0000	216.8	.0000	.5641	.00000	.0000
40.00	768	.0000	5.065	.0000	231.7	.0000	.5474	.00000	.0000
40.83	764	.0000	5.134	.0000	232.1	.0000	.5469	.00000	.0000
80.00	644	.0000	8.071	.0000	243.9	.0000	.5338	.00000	.0000
100.00	608	.0000	9.396	.0000	247.3	.0000	.5301	.00000	.0000
200.00	508	.0000	15.126	.0000	256.4	.0000	.5203	.00000	.0000
300.00	456	.0000	20.033	.0000	260.9	.0000	.5162	.00000	.0000
500.00	398	.0000	28.602	.0000	265.9	.0000	.5118	.00000	.0000
800.00	351	.0000	39.757	.0000	269.8	.0000	.5087	.00000	.0000
1000.00	330	.0000	46.508	.0000	271.4	.0000	.5073	.00000	.0000
1500.00	296	.0000	61.884	.0000	274.2	.0000	.5051	.00000	.0000
R, 0.60; percent fuel, 54.19; O/F, 0.845									
1.00	2169	0.0012					0.6765	0.00025	-.0067
1.05	2149	.0011	2.191	0.0005	34.0	0.0005	.6734	.00022	-.0061
1.60	1982	.0004	1.012	.0001	103.6	.0003	.6514	.00009	-.0026
1.80	1937	.0003	1.000	.0000	115.2	.0003	.6461	.00007	-.0020
2.00	1897	.0002	1.007	-.0000	124.5	.0083	.6417	.00005	-.0016
10.00	1361	-.0001	2.140	-.0001	210.1	.0001	.5870	.00000	.0000
20.00	1169	-.0001	3.331	-.0001	231.9	.0001	.5650	.00000	.0000
20.41	1164	-.0001	3.376	-.0001	232.5	.0001	.5643	.00000	.0000
40.00	998	-.0001	5.295	-.0001	249.1	.0000	.5439	.00000	.0000
40.83	993	-.0001	5.369	-.0001	249.5	.0000	.5433	.00000	.0000
80.00	847	-.0001	8.519	-.0001	262.8	.0000	.5252	.00000	.0000
100.00	803	-.0001	9.944	-.0001	266.6	.0000	.5198	.00000	.0000
200.00	676	-.0001	16.132	-.0001	277.0	.0000	.5049	.00000	.0000
300.00	611	-.0001	21.449	-.0001	282.1	.0000	.4979	.00000	.0000
500.00	536	-.0001	30.751	-.0001	287.8	.0000	.4902	.00000	.0000
800.00	474	-.0001	42.881	-.0001	292.2	.0000	.4846	.00000	.0000
1000.00	447	-.0001	50.232	-.0001	294.2	.0000	.4824	.00000	.0000
1500.00	402	-.0001	66.995	-.0001	297.4	.0000	.4788	.00000	.0000
R, 0.70; percent fuel, 50.34; O/F, 0.986									
1.00	2494	0.0061					0.7547	0.00160	-.0390
1.05	2474	.0057	2.172	0.0018	35.3	0.0023	.7474	.00149	-.0365
1.60	2305	.0030	1.010	.0003	107.5	.0017	.6937	.00075	-.0196
1.78	2262	.0025	1.000	.0000	118.6	.0016	.6824	.00062	-.0164
2.00	2216	.0020	1.009	-.0003	129.3	.0015	.6714	.00050	-.0135
10.00	1633	-.0006	2.185	-.0014	219.6	.0006	.5884	.00001	-.0003
20.00	1418	-.0007	3.431	-.0013	243.0	.0004	.5662	.00000	.0000
20.41	1412	-.0007	3.478	-.0013	243.6	.0004	.5656	.00000	.0000
40.00	1225	-.0007	5.506	-.0013	261.5	.0003	.5447	.00000	.0000
40.83	1219	-.0007	5.585	-.0013	262.0	.0003	.5441	.00000	.0000
80.00	1052	-.0007	8.943	-.0012	276.5	.0002	.5236	.00000	.0000
100.00	1000	-.0007	10.470	-.0012	280.7	.0002	.5172	.00000	.0000
200.00	852	-.0008	17.139	-.0012	292.1	.0002	.4986	.00000	.0000
300.00	773	-.0008	22.897	-.0012	297.8	.0001	.4889	.00000	.0000
500.00	683	-.0008	33.006	-.0012	304.1	.0001	.4781	.00000	.0000
800.00	608	-.0008	46.234	-.0012	309.2	.0001	.4698	.00000	.0000
1000.00	575	-.0008	54.262	-.0012	311.3	.0001	.4662	.00000	.0000
1500.00	519	-.0008	72.597	-.0012	315.0	.0001	.4604	.00000	.0000

TABLE III. - Continued. THERMODYNAMIC DERIVATIVES AT ASSIGNED PRESSURE RATIOS FOR LIQUID AMMONIA AND LIQUID OXYGEN

(a) Continued. Chamber pressure, 300 pounds per square inch absolute; equilibrium composition during isentropic expansion

Pressure ratio, P_c/P	Temperature, T, °K	Temperature exponent, n_T	Area ratio, ε	Area-ratio exponent, n_ε	Specific impulse, I, $\frac{(lb)(sec)}{lb}$	Specific-impulse exponent, n_I	Specific heat, c_p, $(\partial h/\partial T)_P$, (cal)/(g)(°K)	$\left(\frac{\partial \ln \mathscr{M}}{\partial \ln P}\right)_T$	$\left(\frac{\partial \ln \mathscr{M}}{\partial \ln T}\right)_P$
R, 0.80; percent fuel, 47.01; O/F, 1.127									
1.00	2734	0.0148					0.9466	0.00557	-.1262
1.05	2717	.0143	2.151	0.0030	35.8	0.0055	.9545	.00531	-.1210
1.60	2563	.0100	1.008	.0005	109.5	.0047	.8356	.00333	-.0803
1.76	2528	.0091	1.000	.0000	119.7	.0045	.8150	.00296	-.0722
2.00	2482	.0078	1.011	-.0007	131.9	.0042	.7886	.00250	-.0622
10.00	1893	-.0013	2.241	-.0057	225.9	.0019	.5974	.00012	-.0039
20.00	1661	-.0020	3.544	-.0058	250.5	.0014	.5683	.00002	-.0007
20.41	1654	-.0020	3.594	-.0057	251.2	.0014	.5676	.00002	-.0006
40.00	1449	-.0022	5.731	-.0056	270.2	.0011	.5461	.00000	-.0001
40.83	1443	-.0022	5.815	-.0056	270.8	.0011	.5455	.00000	-.0001
80.00	1257	-.0023	9.387	-.0055	286.3	.0008	.5251	.00000	.0000
100.00	1199	-.0024	11.022	-.0054	290.8	.0008	.5184	.00000	.0000
200.00	1033	-.0025	18.203	-.0054	303.2	.0006	.4979	.00000	.0000
300.00	943	-.0025	24.443	-.0053	309.5	.0005	.4867	.00000	.0000
500.00	839	-.0026	35.455	-.0053	316.4	.0004	.4735	.00000	.0000
800.00	752	-.0027	49.927	-.0053	322.0	.0004	.4625	.00000	.0000
1000.00	713	-.0027	58.736	-.0053	324.4	.0004	.4578	.00000	.0000
1500.00	646	-.0027	78.899	-.0053	328.4	.0003	.4500	.00000	.0000
R, 0.90; percent fuel, 44.09; O/F, 1.268									
1.00	2877	0.0229					1.2266	0.01223	-.2662
1.05	2862	.0225	2.134	0.0025	35.9	0.0083	1.2148	.01189	-.2602
1.60	2731	.0189	1.006	.0004	109.8	.0077	1.1072	.00903	-.2073
1.74	2704	.0182	1.000	.0000	119.0	.0075	1.0847	.00848	-.1967
2.00	2661	.0168	1.013	-.0008	132.5	.0073	1.0470	.00761	-.1794
10.00	2135	.0006	2.320	-.0105	229.0	.0045	.6645	.00098	-.0286
20.00	1900	-.0033	3.704	-.0126	254.8	.0034	.5881	.00023	-.0074
20.41	1893	-.0034	3.757	-.0127	255.5	.0034	.5866	.00022	-.0070
40.00	1675	-.0047	6.033	-.0131	275.7	.0026	.5510	.00004	-.0013
40.83	1668	-.0047	6.122	-.0131	276.3	.0026	.5502	.00003	-.0012
80.00	1467	-.0051	9.951	-.0129	292.9	.0020	.5277	.00000	-.0002
100.00	1404	-.0052	11.711	-.0128	297.7	.0019	.5209	.00000	-.0001
200.00	1221	-.0055	19.495	-.0127	311.1	.0015	.5006	.00000	.0000
300.00	1122	-.0056	26.305	-.0126	317.8	.0013	.4887	.00000	.0000
500.00	1006	-.0058	38.394	-.0126	325.4	.0011	.4741	.00000	.0000
800.00	907	-.0059	54.374	-.0126	331.5	.0010	.4616	.00000	.0000
1000.00	863	-.0060	64.136	-.0126	334.2	.0009	.4559	.00000	.0000
1500.00	787	-.0061	86.552	-.0126	338.6	.0008	.4461	.00000	.0000
R, 0.95; percent fuel, 42.76; O/F, 1.339									
1.00	2913	0.0254					1.3349	0.01520	-.3270
1.05	2899	.0250	2.130	0.0020	35.7	0.0092	1.3256	.01468	-.3217
1.60	2774	.0221	1.006	.0003	109.5	.0086	1.2397	.01215	-.2750
1.73	2751	.0215	1.000	.0000	118.2	.0085	1.2220	.01164	-.2656
2.00	2709	.0204	1.014	-.0006	132.1	.0083	1.1901	.01076	-.2496
10.00	2234	.0051	2.364	-.0100	229.1	.0059	.7776	.00254	-.0716
20.00	2015	-.0018	3.808	-.0144	255.6	.0048	.6375	.00078	-.0243
20.41	2008	-.0019	3.863	-.0145	256.3	.0047	.6345	.00074	-.0233
40.00	1791	-.0056	6.237	-.0165	277.1	.0037	.5646	.00015	-.0054
40.83	1784	-.0056	6.330	-.0166	277.7	.0037	.5633	.00015	-.0051
80.00	1577	-.0068	10.324	-.0168	294.8	.0029	.5315	.00002	-.0008
100.00	1512	-.0070	12.164	-.0168	299.8	.0027	.5238	.00001	-.0004
200.00	1321	-.0074	20.318	-.0166	313.7	.0022	.5026	.00000	.0000
300.00	1218	-.0076	27.476	-.0165	320.8	.0019	.4910	.00000	.0000
500.00	1096	-.0078	40.222	-.0165	329.7	.0016	.4762	.00000	.0000
800.00	992	-.0080	57.122	-.0165	335.1	.0014	.4630	.00000	.0000
1000.00	945	-.0081	67.468	-.0165	337.9	.0013	.4571	.00000	.0000
1500.00	864	-.0083	91.270	-.0165	342.5	.0012	.4466	.00000	.0000

TABLE III. - Continued. THERMODYNAMIC DERIVATIVES AT ASSIGNED PRESSURE RATIOS FOR LIQUID AMMONIA AND LIQUID OXYGEN

(a) Continued. Chamber pressure, 300 pounds per square inch absolute; equilibrium composition during isentropic expansion

Pressure ratio, P_c/P	Temperature, T, °K	Temperature exponent, n_T	Area ratio, ε	Area-ratio exponent, n_ε	Specific impulse, I, $\frac{(lb)(sec)}{lb}$	Specific-impulse exponent, n_I	Specific heat, c_p, $(\partial h/\partial T)_P$, (cal)/(g)(°K)	$\left(\frac{\partial \ln \mathscr{M}}{\partial \ln P}\right)_T$	$\left(\frac{\partial \ln \mathscr{M}}{\partial \ln T}\right)_P$
R, 1.00; percent fuel, 41.51; O/F, 1.409									
1.00	2928	0.0262					1.3651	0.01648	-.3522
1.05	2914	.0259	2.128	0.0018	35.5	0.0094	1.3572	.01617	-.3473
1.60	2792	.0233	1.006	.0003	108.8	.0090	1.2845	.01359	-.3050
1.73	2769	.0227	1.000	.0000	117.4	.0089	1.2700	.01318	-.2969
2.00	2728	.0218	1.015	-.0005	131.3	.0087	1.2432	.01229	-.2824
10.00	2283	.0098	2.388	-.0078	228.1	.0067	.9129	.00460	-.1267
20.00	2089	.0039	3.887	-.0115	254.9	.0058	.7746	.00244	-.0735
20.41	2083	.0038	3.945	-.0116	255.6	.0057	.7708	.00239	-.0721
40.00	1891	-.0017	6.453	-.0152	276.8	.0049	.6592	.00106	-.0353
40.83	1885	-.0018	6.551	-.0153	277.4	.0048	.6562	.00103	-.0344
80.00	1691	-.0060	10.799	-.0179	295.2	.0040	.5771	.00036	-.0132
100.00	1627	-.0070	12.756	-.0185	300.4	.0037	.5580	.00024	-.0091
200.00	1434	-.0089	21.438	-.0195	314.9	.0030	.5153	.00005	-.0023
300.00	1326	-.0095	29.067	-.0197	322.3	.0027	.4983	.00002	-.0009
500.00	1199	-.0100	42.681	-.0198	330.6	.0023	.4810	.00000	-.0002
800.00	1089	-.0103	60.786	-.0199	337.4	.0020	.4668	.00000	-.0001
1000.00	1039	-.0105	71.892	-.0199	340.4	.0019	.4604	.00000	.0000
1500.00	953	-.0107	97.495	-.0199	345.3	.0017	.4494	.00000	.0000
R, 1.10; percent fuel, 39.22; O/F, 1.550									
1.00	2913	0.0247					1.2483	0.01454	-.3121
1.05	2898	.0244	2.130	0.0020	34.9	0.0089	1.2393	.01422	-.3068
1.60	2773	.0213	1.006	.0003	107.0	.0083	1.1574	.01151	-.2601
1.74	2749	.0207	1.000	.0000	115.5	.0082	1.1409	.01101	-.2511
2.00	2707	.0197	1.014	-.0006	129.0	.0080	1.1117	.01015	-.2354
10.00	2236	.0064	2.368	-.0085	223.8	.0058	.7848	.00291	-.0834
20.00	2030	.0011	3.836	-.0118	249.8	.0048	.6769	.00137	-.0437
20.41	2023	.0010	3.892	-.0118	250.5	.0048	.6741	.00133	-.0428
40.00	1823	-.0030	6.334	-.0142	271.0	.0040	.5972	.00055	-.0200
40.83	1817	-.0031	6.430	-.0143	271.6	.0039	.5952	.00054	-.0195
80.00	1621	-.0056	10.560	-.0158	288.7	.0032	.5421	.00019	-.0078
100.00	1557	-.0062	12.464	-.0161	293.7	.0030	.5284	.00013	-.0056
200.00	1368	-.0075	20.903	-.0167	307.6	.0024	.4945	.00003	-.0016
300.00	1264	-.0079	28.314	-.0168	314.7	.0021	.4794	.00001	-.0007
500.00	1140	-.0083	41.518	-.0169	322.7	.0018	.4628	.00000	-.0002
800.00	1034	-.0086	59.048	-.0169	329.1	.0016	.4491	.00000	-.0001
1000.00	986	-.0087	69.789	-.0169	332.0	.0015	.4431	.00000	.0000
1500.00	903	-.0089	94.526	-.0170	336.7	.0013	.4327	.00000	.0000
R, 1.20; percent fuel, 37.16; O/F, 1.691									
1.00	2871	0.0222					1.1178	0.01176	-.2575
1.05	2856	.0219	2.133	0.0021	34.2	0.0080	1.1093	.01147	-.2525
1.60	2726	.0188	1.006	.0003	104.9	.0075	1.0346	.00906	-.2100
1.74	2701	.0182	1.000	.0000	113.5	.0074	1.0197	.00863	-.2019
2.00	2659	.0171	1.014	-.0006	126.5	.0072	.9945	.00791	-.1884
10.00	2175	.0050	2.355	-.0077	219.2	.0050	.7271	.00221	-.0662
20.00	1968	.0006	3.805	-.0105	244.4	.0042	.6378	.00105	-.0352
20.41	1962	.0005	3.861	-.0105	245.1	.0042	.6355	.00103	-.0344
40.00	1762	-.0029	6.270	-.0126	265.1	.0034	.5686	.00043	-.0161
40.83	1756	-.0029	6.364	-.0126	265.6	.0034	.5669	.00041	-.0157
80.00	1562	-.0051	10.432	-.0139	282.2	.0028	.5192	.00014	-.0061
100.00	1499	-.0056	12.304	-.0141	287.0	.0026	.5067	.00009	-.0042
200.00	1314	-.0066	20.590	-.0146	300.5	.0021	.4759	.00002	-.0012
300.00	1212	-.0070	27.856	-.0147	307.3	.0018	.4620	.00001	-.0005
500.00	1091	-.0073	40.785	-.0147	315.0	.0016	.4465	.00000	-.0001
800.00	988	-.0076	57.925	-.0148	321.2	.0014	.4338	.00000	.0000
1000.00	941	-.0077	68.417	-.0148	323.9	.0013	.4281	.00000	.0000
1500.00	861	-.0078	92.559	-.0148	328.4	.0011	.4183	.00000	.0000
R, 1.50; percent fuel, 32.12; O/F, 2.114									
1.00	2728	0.0173					0.9074	0.00731	-.1719
1.05	2712	.0170	2.138	0.0019	32.5	0.0064	.9009	.00710	-.1682
1.60	2579	.0142	1.007	.0003	99.3	.0059	.8450	.00549	-.1376
1.74	2551	.0136	1.000	.0000	107.8	.0058	.8335	.00519	-.1316
2.00	2509	.0127	1.013	-.0005	119.8	.0056	.8152	.00473	-.1223
10.00	2013	.0026	2.325	-.0066	206.9	.0038	.6144	.00117	-.0386
20.00	1804	-.0007	3.732	-.0087	230.4	.0030	.5472	.00050	-.0187
20.41	1798	-.0008	3.786	-.0087	231.0	.0030	.5455	.00049	-.0182
40.00	1600	-.0030	6.106	-.0100	249.4	.0024	.4971	.00018	-.0074
40.83	1594	-.0031	6.197	-.0101	249.9	.0024	.4959	.00017	-.0072
80.00	1405	-.0043	10.088	-.0107	265.1	.0019	.4620	.00005	-.0023
100.00	1345	-.0046	11.874	-.0108	269.5	.0018	.4532	.00003	-.0015
200.00	1170	-.0051	19.750	-.0109	281.8	.0014	.4310	.00001	-.0003
300.00	1075	-.0053	26.630	-.0109	288.0	.0013	.4199	.00000	-.0001
500.00	963	-.0055	38.831	-.0109	294.9	.0011	.4075	.00000	.0000
800.00	868	-.0056	54.950	-.0109	300.5	.0009	.3969	.00000	.0000
1000.00	825	-.0057	64.794	-.0109	302.9	.0009	.3928	.00000	.0000
1500.00	752	-.0058	87.389	-.0110	306.9	.0008	.3840	.00000	.0000

TABLE III. - Continued. THERMODYNAMIC DERIVATIVES AT ASSIGNED PRESSURE RATIOS FOR LIQUID AMMONIA AND LIQUID OXYGEN

(a) Concluded. Chamber pressure, 300 pounds per square inch absolute; equilibrium composition during isentropic expansion

Pressure ratio, P_c/P	Temperature, T, °K	Temperature exponent, n_T	Area ratio, ε	Area-ratio exponent, n_ε	Specific impulse, I, $\frac{(lb)(sec)}{lb}$	Specific-impulse exponent, n_I	Specific heat, c_p, $(\partial h/\partial T)_p$, (cal)/(g)(°K)	$\left(\frac{\partial \ln \mathcal{M}}{\partial \ln P}\right)_T$	$\left(\frac{\partial \ln \mathcal{M}}{\partial \ln T}\right)_p$
R, 2.00; percent fuel, 26.19; O/F, 2.818									
1.00	2515	0.0122					0.7201	0.00397	-.1032
1.05	2499	.0119	2.147	0.0018	30.1	0.0047	.7148	.00383	-.1004
1.60	2362	.0094	1.008	.0003	92.1	.0042	.6684	.00280	-.0781
1.75	2332	.0089	1.000	.0000	100.4	.0041	.6584	.00260	-.0735
2.00	2290	.0081	1.012	-.0005	111.0	.0040	.6441	.00233	-.0672
10.00	1782	.0003	2.275	-.0052	190.7	.0023	.4949	.00039	-.0148
20.00	1574	-.0016	3.612	-.0063	211.8	.0018	.4530	.00013	-.0056
20.41	1568	-.0016	3.663	-.0063	212.4	.0018	.4520	.00013	-.0054
40.00	1377	-.0025	5.849	-.0068	228.8	.0014	.4238	.00003	-.0016
40.83	1371	-.0026	5.934	-.0068	229.3	.0014	.4230	.00003	-.0016
80.00	1195	-.0030	9.579	-.0069	242.6	.0011	.4033	.00001	-.0004
100.00	1141	-.0030	11.245	-.0068	246.5	.0010	.3977	.00000	-.0002
200.00	982	-.0032	18.564	-.0068	257.2	.0008	.3821	.00000	.0000
300.00	898	-.0033	24.925	-.0068	262.5	.0007	.3738	.00000	.0000
500.00	799	-.0034	36.156	-.0068	268.5	.0006	.3639	.00000	.0000
800.00	716	-.0035	50.923	-.0068	273.3	.0005	.3556	.00000	.0000
1000.00	679	-.0035	59.913	-.0068	275.4	.0005	.3519	.00000	.0000
1500.00	616	-.0036	80.490	-.0068	278.8	.0004	.3455	.00000	.0000
R, 3.00; percent fuel, 19.13; O/F, 4.227									
1.00	2163	0.0056					0.5151	0.00120	-.0368
1.05	2146	.0054	2.168	0.0014	26.8	0.0023	.5112	.00114	-.0353
1.60	2004	.0036	1.009	.0003	81.7	.0019	.4795	.00071	-.0237
1.78	1969	.0032	1.000	.0000	90.0	.0018	.4721	.00063	-.0213
2.00	1929	.0027	1.009	-.0003	98.3	.0017	.4641	.00054	-.0187
10.00	1427	-.0006	2.189	-.0022	167.3	.0008	.3878	.00004	-.0017
20.00	1236	-.0009	3.429	-.0023	185.1	.0006	.3700	.00001	-.0004
20.41	1231	-.0009	3.476	-.0023	185.5	.0006	.3696	.00001	-.0004
40.00	1065	-.0010	5.488	-.0022	199.1	.0004	.3558	.00000	-.0001
40.83	1060	-.0010	5.566	-.0022	199.5	.0004	.3554	.00000	-.0001
80.00	912	-.0011	8.893	-.0022	210.5	.0003	.3434	.00000	.0000
100.00	866	-.0011	10.406	-.0022	213.7	.0003	.3396	.00000	.0000
200.00	737	-.0011	17.008	-.0021	222.3	.0002	.3282	.00000	.0000
300.00	668	-.0011	22.703	-.0021	226.6	.0002	.3221	.00000	.0000
500.00	590	-.0011	32.694	-.0021	231.4	.0002	.3148	.00000	.0000
800.00	524	-.0012	45.747	-.0021	235.2	.0001	.3089	.00000	.0000
1000.00	495	-.0012	53.660	-.0021	236.8	.0001	.3063	.00000	.0000
1500.00	446	-.0012	71.702	-.0021	239.6	.0001	.3019	.00000	.0000
R, 4.00; percent fuel, 15.07; O/F, 5.636									
1.00	1875	0.0021					0.4158	0.00033	-.0119
1.05	1858	.0020	2.187	0.0007	24.3	0.0009	.4133	.00031	-.0112
1.60	1717	.0011	1.011	.0001	74.1	.0007	.3939	.00016	-.0064
1.80	1680	.0009	1.000	.0000	82.3	.0006	.3893	.00013	-.0054
2.00	1645	.0007	1.007	-.0001	89.1	.0006	.3853	.00011	-.0045
10.00	1179	-.0002	2.137	-.0006	150.4	.0002	.3442	.00000	-.0002
20.00	1012	-.0003	3.323	-.0006	166.0	.0002	.3322	.00000	.0000
20.41	1007	-.0003	3.368	-.0006	166.4	.0002	.3319	.00000	.0000
40.00	864	-.0003	5.282	-.0005	178.2	.0001	.3215	.00000	.0000
40.83	859	-.0003	5.356	-.0005	178.6	.0001	.3211	.00000	.0000
80.00	733	-.0003	8.500	-.0005	188.0	.0001	.3110	.00000	.0000
100.00	695	-.0003	9.924	-.0005	190.8	.0001	.3078	.00000	.0000
200.00	585	-.0003	16.104	-.0005	198.2	.0001	.2983	.00000	.0000
300.00	528	-.0003	21.408	-.0005	201.8	.0001	.2934	.00000	.0000
500.00	463	-.0003	30.675	-.0005	205.9	.0000	.2877	.00000	.0000
800.00	410	-.0003	42.731	-.0005	209.1	.0000	.2834	.00000	.0000
1000.00	386	-.0003	50.025	-.0005	210.5	.0000	.2818	.00000	.0000
1500.00	347	-.0004	66.635	-.0005	212.7	.0000	.2794	.00000	.0000
R, 5.00; percent fuel, 12.43; O/F, 7.046									
1.00	1640	0.0007					0.3655	0.00009	-.0035
1.05	1624	.0006	2.200	0.0003	22.4	0.0003	.3640	.00008	-.0033
1.60	1491	.0003	1.013	.0000	68.1	.0002	.3523	.00003	-.0016
1.81	1453	.0002	1.000	.0000	76.1	.0002	.3493	.00003	-.0012
2.00	1424	.0002	1.006	-.0000	81.8	.0002	.3470	.00002	-.0010
10.00	1002	-.0001	2.106	-.0001	137.5	.0001	.3191	.00000	.0000
20.00	853	-.0001	3.257	-.0001	151.5	.0000	.3091	.00000	.0000
20.41	849	-.0001	3.301	-.0001	151.9	.0000	.3088	.00000	.0000
40.00	723	-.0001	5.149	-.0001	162.5	.0000	.2993	.00000	.0000
40.83	720	-.0001	5.221	-.0001	162.8	.0000	.2990	.00000	.0000
80.00	610	-.0001	8.241	-.0001	171.2	.0000	.2899	.00000	.0000
100.00	577	-.0001	9.603	-.0001	173.6	.0000	.2871	.00000	.0000
200.00	483	-.0001	15.499	-.0001	180.2	.0000	.2792	.00000	.0000
300.00	434	-.0001	20.540	-.0001	183.4	.0000	.2751	.00000	.0000
500.00	379	-.0001	29.326	-.0001	186.9	.0000	.2712	.00000	.0000
800.00	334	-.0001	40.744	-.0001	189.7	.0000	.2687	.00000	.0000
1000.00	315	-.0001	47.646	-.0001	190.9	.0000	.2677	.00000	.0000
1500.00	282	-.0001	63.359	-.0001	192.9	.0000	.2664	.00000	.0000

TABLE III. - Continued. THERMODYNAMIC DERIVATIVES AT ASSIGNED PRESSURE RATIOS FOR LIQUID AMMONIA AND LIQUID OXYGEN

(b) Chamber pressure, 300 pounds per square inch absolute; frozen composition during isentropic expansion

Pressure ratio, P_c/P	Temperature, T, $^{\circ}K$	Temperature exponent, n_T	Area ratio, ε	Area-ratio exponent, n_ε	Specific impulse, I, $\frac{(lb)(sec)}{lb}$	Specific-impulse exponent, n_I
R, 0.40; percent fuel, 63.95; O/F, 0.564						
1.05	1334	0.0000	2.226	0.0000	29.1	0.0000
1.60	1210	.0000	1.015	.0000	88.3	.0000
2.00	1148	.0000	1.004	.0000	105.9	.0000
10.00	772	.0000	2.030	.0000	176.3	.0000
20.00	646	.0000	3.093	.0000	193.5	.0000
20.41	643	.0000	3.133	.0000	193.9	.0000
40.00	538	.0000	4.823	.0000	206.8	.0000
40.83	535	.0000	4.888	.0000	207.1	.0000
80.00	447	.0000	7.629	.0000	217.2	.0000
100.00	421	.0000	8.863	.0000	220.1	.0000
200.00	349	.0000	14.191	.0000	227.8	.0000
300.00	312	.0000	18.744	.0000	231.6	.0000
500.00	271	.0000	26.680	.0000	235.7	.0000
800.00	238	.0000	36.978	.0000	239.0	.0000
1000.00	224	.0000	43.187	.0000	240.4	.0000
1500.00	200	.0000	57.266	.0000	242.7	.0000
R, 0.50; percent fuel, 58.67; O/F, 0.705						
1.05	1766	0.0001	2.206	0.0000	32.1	0.0001
1.60	1617	.0001	1.013	.0000	97.5	.0000
2.00	1541	.0001	1.006	.0000	117.1	.0000
10.00	1074	.0001	2.090	.0000	196.4	.0000
20.00	911	.0001	3.218	.0000	216.2	.0000
20.41	906	.0001	3.261	.0000	216.8	.0000
40.00	768	.0001	5.064	.0000	231.7	.0000
40.83	764	.0001	5.134	.0000	232.1	.0000
80.00	644	.0001	8.071	.0000	243.9	.0000
100.00	608	.0001	9.395	.0000	247.3	.0000
200.00	508	.0001	15.125	.0000	256.4	.0000
300.00	456	.0001	20.032	.0000	260.9	.0000
500.00	398	.0001	28.600	.0000	265.8	.0000
800.00	351	.0001	39.755	.0000	269.7	.0000
1000.00	330	.0001	46.505	.0000	271.4	.0000
1500.00	296	.0001	61.880	.0000	274.2	.0000
R, 0.60; percent fuel, 54.19; O/F, 0.845						
1.05	2149	0.0011	2.193	0.0001	34.0	0.0005
1.60	1979	.0011	1.012	.0000	103.6	.0004
2.00	1893	.0011	1.007	.0000	124.4	.0004
10.00	1357	.0013	2.139	.0001	209.9	.0005
20.00	1165	.0013	3.328	.0002	231.7	.0005
20.41	1160	.0013	3.373	.0002	232.2	.0005
40.00	994	.0014	5.291	.0003	248.8	.0005
40.83	990	.0014	5.365	.0003	249.2	.0005
80.00	844	.0015	8.510	.0003	262.5	.0005
100.00	799	.0015	9.934	.0003	266.3	.0005
200.00	674	.0016	16.114	.0004	276.6	.0005
300.00	608	.0016	21.423	.0004	281.8	.0005
500.00	533	.0017	30.711	.0005	287.4	.0005
800.00	472	.0017	42.823	.0005	291.9	.0005
1000.00	445	.0017	50.162	.0005	293.8	.0006
1500.00	400	.0017	66.899	.0005	297.0	.0006
R, 0.70; percent fuel, 50.34; O/F, 0.986						
1.05	2472	0.0054	2.183	0.0003	35.2	0.0022
1.60	2286	.0055	1.011	.0000	107.3	.0021
2.00	2193	.0056	1.008	.0000	129.0	.0021
10.00	1604	.0064	2.175	.0006	218.6	.0023
20.00	1391	.0068	3.413	.0010	241.7	.0024
20.41	1385	.0068	3.460	.0010	242.3	.0024
40.00	1200	.0072	5.473	.0013	260.0	.0024
40.83	1195	.0072	5.551	.0013	260.5	.0024
80.00	1029	.0076	8.882	.0017	274.8	.0025
100.00	978	.0078	10.396	.0018	278.9	.0025
200.00	832	.0082	17.002	.0021	290.2	.0026
300.00	755	.0084	22.701	.0023	295.8	.0026
500.00	666	.0087	32.704	.0026	302.1	.0027
800.00	593	.0089	45.786	.0028	307.0	.0027
1000.00	560	.0090	53.725	.0028	309.2	.0027
1500.00	505	.0092	71.849	.0030	312.7	.0028

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TABLE III. - Continued. THERMODYNAMIC DERIVATIVES AT ASSIGNED PRESSURE RATIOS FOR LIQUID AMMONIA AND LIQUID OXYGEN

(b) Continued. Chamber pressure, 300 pounds per square inch absolute; frozen composition during isentropic expansion

Pressure ratio, P_c/P	Temperature, T, °K	Temperature exponent, n_T	Area ratio, ε	Area-ratio exponent, n_ε	Specific impulse, I, $\frac{(lb)(sec)}{lb}$	Specific-impulse exponent, n_I
R, 0.80; percent fuel, 47.01; O/F, 1.127						
1.05	2711	0.0137	2.177	0.0004	35.8	0.0051
1.60	2515	.0141	1.010	.0001	109.1	.0052
2.00	2416	.0143	1.009	.0001	131.2	.0053
10.00	1790	.0163	2.200	.0016	222.9	.0057
20.00	1564	.0172	3.471	.0024	246.8	.0059
20.41	1557	.0172	3.519	.0024	247.4	.0059
40.00	1359	.0183	5.599	.0033	265.8	.0060
40.83	1353	.0183	5.680	.0033	266.3	.0060
80.00	1174	.0194	9.146	.0042	281.3	.0062
100.00	1119	.0198	10.728	.0046	285.6	.0063
200.00	959	.0210	17.662	.0056	297.5	.0064
300.00	874	.0217	23.671	.0062	303.5	.0065
500.00	776	.0226	34.253	.0069	310.1	.0067
800.00	693	.0233	48.133	.0076	315.5	.0068
1000.00	656	.0236	56.572	.0078	317.7	.0068
1500.00	594	.0242	75.868	.0083	321.6	.0069
R, 0.90; percent fuel, 44.09; O/F, 1.268						
1.05	2853	0.0221	2.174	0.0007	35.8	0.0081
1.60	2651	.0227	1.010	.0001	109.2	.0082
2.00	2549	.0231	1.009	.0002	131.4	.0083
10.00	1904	.0262	2.214	.0026	223.6	.0090
20.00	1669	.0277	3.503	.0038	247.7	.0092
20.41	1662	.0278	3.553	.0039	248.4	.0093
40.00	1456	.0295	5.672	.0053	267.0	.0095
40.83	1450	.0295	5.755	.0053	267.6	.0095
80.00	1264	.0313	9.300	.0068	282.8	.0098
100.00	1206	.0320	10.923	.0074	287.2	.0099
200.00	1039	.0340	18.057	.0091	299.4	.0102
300.00	950	.0352	24.258	.0101	305.5	.0104
500.00	846	.0367	35.206	.0114	312.3	.0106
800.00	758	.0380	49.600	.0126	317.8	.0107
1000.00	719	.0386	58.362	.0131	320.2	.0108
1500.00	652	.0396	78.422	.0140	324.2	.0110
R, 0.95; percent fuel, 42.76; O/F, 1.339						
1.05	2889	0.0247	2.173	0.0007	35.7	0.0089
1.60	2686	.0255	1.010	.0002	108.8	.0091
2.00	2583	.0259	1.009	.0002	130.9	.0092
10.00	1932	.0293	2.217	.0029	222.9	.0100
20.00	1696	.0310	3.512	.0043	247.0	.0103
20.41	1689	.0311	3.561	.0043	247.6	.0103
40.00	1481	.0330	5.691	.0059	266.3	.0106
40.83	1475	.0330	5.774	.0059	266.8	.0106
80.00	1287	.0351	9.341	.0076	282.0	.0109
100.00	1229	.0358	10.974	.0082	286.4	.0110
200.00	1060	.0380	18.161	.0102	298.6	.0114
300.00	970	.0394	24.414	.0114	304.8	.0115
500.00	864	.0411	35.461	.0128	311.6	.0118
800.00	775	.0426	49.995	.0141	317.1	.0120
1000.00	735	.0433	58.846	.0148	319.5	.0121
1500.00	667	.0445	79.117	.0158	323.5	.0122

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TABLE III. - Continued. THERMODYNAMIC DERIVATIVES AT ASSIGNED PRESSURE RATIOS FOR LIQUID AMMONIA AND LIQUID OXYGEN

(b) Continued. Chamber pressure, 300 pounds per square inch absolute; frozen composition during isentropic expansion

Pressure ratio, P_0/P	Temperature, T, °K	Temperature exponent, n_T	Area ratio, ε	Area-ratio exponent, n_ε	Specific impulse, I, $\frac{(lb)(sec)}{lb}$	Specific-impulse exponent, n_I
R, 1.00; percent fuel, 41.51; O/F, 1.409						
1.05	2904	0.0257	2.172	0.0007	35.5	0.0092
1.60	2700	.0265	1.010	.0001	108.2	.0094
2.00	2597	.0269	1.009	.0002	130.1	.0095
10.00	1945	.0305	2.219	.0030	221.5	.0103
20.00	1707	.0323	3.516	.0045	245.5	.0106
20.41	1700	.0323	3.565	.0045	246.1	.0106
40.00	1492	.0343	5.700	.0061	264.7	.0110
40.83	1486	.0343	5.783	.0062	265.2	.0110
80.00	1298	.0364	9.360	.0079	280.4	.0113
100.00	1239	.0372	10.999	.0086	284.8	.0114
200.00	1070	.0395	18.211	.0106	297.0	.0118
300.00	979	.0410	24.489	.0118	303.1	.0119
500.00	872	.0427	35.585	.0134	309.9	.0122
800.00	783	.0443	50.188	.0148	315.4	.0184
1000.00	743	.0451	59.083	.0154	317.8	.0125
1500.00	674	.0463	79.460	.0165	321.8	.0127
R, 1.10; percent fuel, 39.22; O/F, 1.550						
1.05	2889	0.0240	2.172	0.0007	34.9	0.0086
1.60	2686	.0247	1.010	.0001	106.3	.0088
2.00	2583	.0252	1.009	.0002	127.9	.0089
10.00	1934	.0285	2.218	.0028	217.8	.0096
20.00	1697	.0302	3.514	.0042	241.3	.0099
20.41	1691	.0302	3.564	.0042	241.9	.0099
40.00	1483	.0321	5.697	.0057	260.2	.0103
40.83	1477	.0321	5.780	.0058	260.7	.0103
80.00	1290	.0341	9.354	.0075	275.6	.0106
100.00	1232	.0348	10.992	.0080	280.0	.0107
200.00	1063	.0370	18.199	.0099	291.9	.0110
300.00	973	.0383	24.472	.0111	297.9	.0112
500.00	867	.0400	35.559	.0125	304.6	.0114
800.00	778	.0415	50.151	.0138	310.0	.0116
1000.00	738	.0422	59.040	.0144	312.4	.0117
1500.00	670	.0434	79.401	.0155	316.3	.0118
R, 1.20; percent fuel, 37.16; O/F, 1.691						
1.05	2847	0.0214	2.173	0.0007	34.2	0.0079
1.60	2646	.0221	1.010	.0001	104.3	.0079
2.00	2545	.0225	1.009	.0001	125.5	.0080
10.00	1902	.0255	2.215	.0025	213.6	.0087
20.00	1668	.0270	3.507	.0038	236.6	.0089
20.41	1662	.0270	3.557	.0038	237.2	.0090
40.00	1457	.0287	5.682	.0051	255.1	.0092
40.83	1451	.0287	5.765	.0052	255.6	.0092
80.00	1265	.0305	9.322	.0067	270.2	.0095
100.00	1208	.0311	10.952	.0072	274.4	.0096
200.00	1042	.0331	18.119	.0089	286.1	.0099
300.00	953	.0343	24.354	.0099	292.0	.0100
500.00	849	.0357	35.368	.0112	298.5	.0102
800.00	761	.0371	49.859	.0123	303.8	.0104
1000.00	722	.0377	58.683	.0129	306.0	.0105
1500.00	655	.0387	78.894	.0138	309.8	.0106
R, 1.50; percent fuel, 32.12; O/F, 2.114						
1.05	2705	0.0166	2.176	0.0005	32.4	0.0062
1.60	2510	.0171	1.010	.0001	98.8	.0063
2.00	2412	.0174	1.009	.0001	118.9	.0064
10.00	1792	.0197	2.204	.0026	202.0	.0069
20.00	1567	.0209	3.481	.0029	223.7	.0071
20.41	1561	.0209	3.530	.0029	224.3	.0071
40.00	1364	.0222	5.625	.0040	241.1	.0073
40.83	1358	.0222	5.706	.0040	241.5	.0073
80.00	1181	.0235	9.203	.0051	255.1	.0075
100.00	1126	.0240	10.802	.0055	259.1	.0076
200.00	968	.0255	17.821	.0068	270.0	.0078
300.00	884	.0263	23.916	.0075	275.5	.0079
500.00	785	.0274	34.666	.0085	281.5	.0081
800.00	703	.0284	48.787	.0093	286.4	.0082
1000.00	666	.0288	57.379	.0097	288.5	.0083
1500.00	604	.0296	77.038	.0103	292.0	.0084

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TABLE III. - Continued. THERMODYNAMIC DERIVATIVES AT ASSIGNED PRESSURE RATIOS FOR LIQUID AMMONIA AND LIQUID OXYGEN

(b) Concluded. Chamber pressure, 300 pounds per square inch absolute; frozen composition during isentropic expansion

Pressure ratio, P_c/P	Temperature, T, °K	Temperature exponent, n_T	Area ratio, ε	Area-ratio exponent, n_ε	Specific impulse, I, $\frac{(lb)(sec)}{lb}$	Specific-impulse exponent, n_I
R, 2.00; percent fuel, 26.19; O/F, 2.818						
1.05	2493	0.0116	2.181	0.0004	30.1	0.0046
1.60	2309	.0120	1.010	.0001	91.7	.0046
2.00	2216	.0122	1.008	.0001	110.2	.0047
10.00	1630	.0138	2.186	.0013	187.0	.0050
20.00	1419	.0146	3.440	.0020	206.9	.0051
20.41	1413	.0146	3.487	.0020	207.4	.0052
40.00	1229	.0155	5.535	.0027	222.7	.0053
40.83	1224	.0155	5.615	.0027	223.1	.0053
80.00	1059	.0164	9.020	.0035	235.5	.0054
100.00	1008	.0167	10.572	.0038	239.1	.0055
200.00	862	.0177	17.371	.0046	249.0	.0056
300.00	785	.0182	23.257	.0050	253.9	.0057
500.00	695	.0189	33.615	.0056	259.3	.0058
800.00	620	.0195	47.191	.0061	263.7	.0059
1000.00	587	.0197	55.438	.0063	265.6	.0059
1500.00	531	.0202	74.282	.0067	268.8	.0060
R, 3.00; percent fuel, 19.13; O/F, 4.227						
1.05	2143	0.0053	2.189	0.0001	26.8	0.0021
1.60	1976	.0054	1.011	.0000	81.5	.0022
2.00	1892	.0055	1.007	.0000	97.9	.0022
10.00	1368	.0062	2.154	.0006	165.5	.0024
20.00	1180	.0065	3.367	.0008	182.8	.0024
20.41	1175	.0065	3.413	.0008	183.2	.0024
40.00	1014	.0069	5.381	.0011	196.4	.0025
40.83	1009	.0069	5.457	.0011	196.8	.0025
80.00	866	.0073	8.707	.0014	207.4	.0026
100.00	822	.0074	10.183	.0015	210.5	.0026
200.00	698	.0077	16.615	.0018	218.9	.0026
300.00	632	.0079	22.157	.0020	223.0	.0027
500.00	557	.0082	31.869	.0022	227.6	.0027
800.00	494	.0084	44.547	.0024	231.3	.0027
1000.00	467	.0085	52.227	.0025	232.9	.0027
1500.00	420	.0086	69.732	.0026	235.5	.0028
R, 4.00; percent fuel, 15.07; O/F, 5.636						
1.05	1857	0.0020	2.198	0.0001	24.3	0.0009
1.60	1706	.0020	1.012	.0000	74.0	.0009
2.00	1630	.0021	1.007	.0000	88.9	.0009
10.00	1160	.0023	2.126	.0002	149.7	.0009
20.00	994	.0024	3.304	.0003	165.1	.0009
20.41	989	.0024	3.349	.0003	165.5	.0009
40.00	848	.0026	5.250	.0004	177.2	.0010
40.83	844	.0026	5.324	.0004	177.5	.0010
80.00	719	.0027	8.445	.0005	186.9	.0010
100.00	681	.0027	9.857	.0005	189.6	.0010
200.00	574	.0028	15.988	.0006	196.9	.0010
300.00	518	.0029	21.247	.0007	200.5	.0010
500.00	454	.0030	30.433	.0007	204.5	.0010
800.00	401	.0030	42.383	.0008	207.7	.0010
1000.00	378	.0030	49.612	.0008	209.0	.0010
1500.00	339	.0031	66.074	.0008	211.3	.0011
R, 5.00; percent fuel, 12.43; O/F, 7.046						
1.05	1624	0.0006	2.205	0.0000	22.4	0.0003
1.60	1487	.0007	1.013	.0000	68.1	.0003
2.00	1418	.0007	1.006	.0000	81.7	.0003
10.00	995	.0007	2.103	.0001	137.2	.0003
20.00	848	.0008	3.252	.0001	151.2	.0003
20.41	844	.0008	3.295	.0001	151.6	.0003
40.00	719	.0008	5.140	.0001	162.1	.0003
40.83	715	.0008	5.211	.0001	162.4	.0003
80.00	606	.0009	8.225	.0001	170.8	.0003
100.00	573	.0009	9.584	.0002	173.2	.0003
200.00	479	.0009	15.466	.0002	179.7	.0003
300.00	431	.0009	20.494	.0002	182.9	.0003
500.00	376	.0009	29.258	.0002	186.4	.0003
800.00	332	.0009	40.647	.0002	189.2	.0003
1000.00	312	.0009	47.533	.0002	190.4	.0003
1500.00	280	.0009	63.206	.0002	192.4	.0003

TABLE III. - Continued. THERMODYNAMIC DERIVATIVES AT ASSIGNED PRESSURE RATIOS FOR LIQUID AMMONIA AND LIQUID OXYGEN

(c) Chamber pressure, 600 pounds per square inch absolute; equilibrium composition during isentropic expansion

Pressure ratio, P_c/P	Temperature, T, °K	Temperature exponent, n_T	Area ratio, ε	Area-ratio exponent, n_ϵ	Specific impulse, I, $\frac{(lb)(sec)}{lb}$	Specific-impulse exponent, n_I	Specific heat, c_p, $(\partial h/\partial T)_p$, (cal)/(g)(°K)	$\left(\frac{\partial \ln \mathcal{M}}{\partial \ln P}\right)_T$	$\left(\frac{\partial \ln \mathcal{M}}{\partial \ln T}\right)_p$
R, 0.40; percent fuel, 63.95; O/F, 0.564									
1.00	1349	0.0000					0.6540	0.00000	0.0000
1.05	1334	.0000	2.226	0.0000	29.1	0.0000	.6524	.00000	.0000
1.60	1210	.0000	1.015	.0000	88.3	.0000	.6381	.00000	.0000
1.84	1171	.0000	1.000	.0000	99.7	.0000	.6335	.00000	.0000
2.00	1148	.0000	1.004	.0000	105.9	.0000	.6307	.00000	.0000
10.00	772	.0000	2.030	.0000	176.3	.0000	.5855	.00000	.0000
20.00	646	.0000	3.093	.0000	193.5	.0000	.5720	.00000	.0000
20.41	643	.0000	3.133	.0000	193.9	.0000	.5717	.00000	.0000
40.00	538	.0000	4.823	.0000	206.8	.0000	.5618	.00000	.0000
40.83	535	.0000	4.888	.0000	207.1	.0000	.5616	.00000	.0000
80.00	447	.0000	7.629	.0000	217.2	.0000	.5547	.00000	.0000
100.00	421	.0000	8.863	.0000	220.1	.0000	.5530	.00000	.0000
200.00	349	.0000	14.191	.0000	227.8	.0000	.5478	.00000	.0000
300.00	312	.0000	18.744	.0000	231.6	.0000	.5454	.00000	.0000
500.00	271	.0000	26.680	.0000	235.7	.0000	.5427	.00000	.0000
800.00	238	.0000	36.978	.0000	239.0	.0000	.5377	.00000	.0000
1000.00	224	.0000	43.187	.0000	240.4	.0000	.5344	.00000	.0000
1500.00	200	.0000	57.266	.0000	242.7	.0000	.5294	.00000	.0000
						.0000	.0000	.00000	.0000
R, 0.50; percent fuel, 58.67; O/F, 0.705									
1.00	1784	0.0001					0.6602	0.00001	-.0003
1.05	1766	.0001	2.206	0.0000	32.1	0.0000	.6585	.00001	-.0003
1.60	1617	.0000	1.013	.0000	97.5	.0000	.6448	.00000	-.0001
1.82	1574	.0000	1.000	.0000	109.2	.0000	.6407	.00000	-.0001
2.00	1542	.0000	1.006	.0000	117.1	.0000	.6375	.00000	.0000
10.00	1075	.0000	2.090	.0000	196.4	.0000	.5847	.00000	.0000
20.00	911	.0000	3.218	.0000	216.3	.0000	.5646	.00000	.0000
20.41	906	.0000	3.261	.0000	216.8	.0000	.5641	.00000	.0000
40.00	768	.0000	5.065	.0000	231.7	.0000	.5474	.00000	.0000
40.83	764	.0000	5.134	.0000	232.1	.0000	.5469	.00000	.0000
80.00	644	.0000	8.071	.0000	243.9	.0000	.5337	.00000	.0000
100.00	608	.0000	9.396	.0000	247.3	.0000	.5301	.00000	.0000
200.00	508	.0000	15.126	.0000	256.4	.0000	.5202	.00000	.0000
300.00	456	.0000	20.033	.0000	260.9	.0000	.5162	.00000	.0000
500.00	398	.0000	28.602	.0000	265.9	.0000	.5121	.00000	.0000
800.00	351	.0000	39.757	.0000	269.8	.0000	.5087	.00000	.0000
1000.00	330	.0000	46.508	.0000	271.4	.0000	.5072	.00000	.0000
1500.00	296	.0000	61.884	.0000	274.2	.0000	.5054	.00000	.0000
R, 0.60; percent fuel, 54.19; O/F, 0.845									
1.00	2171	0.0009					0.6700	0.00018	-.0047
1.05	2151	.0008	2.191	0.0003	34.1	0.0003	.6675	.00016	-.0043
1.60	1983	.0003	1.012	.0000	103.6	.0002	.6486	.00006	-.0018
1.80	1938	.0002	1.000	.0000	115.2	.0002	.6440	.00005	-.0014
2.00	1898	.0002	1.007	-.0000	124.5	.0002	.6399	.00004	-.0011
10.00	1361	-.0001	2.140	-.0001	210.1	.0001	.5870	.00000	.0000
20.00	1169	-.0001	3.330	-.0001	231.9	.0000	.5650	.00000	.0000
20.41	1164	-.0001	3.375	-.0001	232.5	.0000	.5643	.00000	.0000
40.00	998	-.0001	5.295	-.0001	249.1	.0000	.5439	.00000	.0000
40.83	993	-.0001	5.369	-.0001	249.5	.0000	.5433	.00000	.0000
80.00	847	-.0001	8.518	-.0001	262.8	.0000	.5252	.00000	.0000
100.00	803	-.0001	9.943	-.0001	266.6	.0000	.5197	.00000	.0000
200.00	676	-.0001	16.131	-.0001	277.0	.0000	.5050	.00000	.0000
300.00	611	-.0001	21.448	-.0001	282.1	.0000	.4979	.00000	.0000
500.00	536	-.0001	30.749	-.0001	287.8	.0000	.4902	.00000	.0000
800.00	474	-.0001	42.879	-.0001	292.3	.0000	.4845	.00000	.0000
1000.00	447	-.0001	50.228	-.0001	294.2	.0000	.4824	.00000	.0000
1500.00	402	-.0001	66.991	-.0001	297.4	.0000	.4789	.00000	.0000
						.0000	.0000	.00000	.0000
R, 0.70; percent fuel, 50.34; O/F, 0.986									
1.00	2503	0.0047					0.7252	0.00119	-.0287
1.05	2483	.0044	2.175	0.0015	35.3	0.0017	.7195	.00110	-.0268
1.60	2309	.0022	1.010	.0002	107.6	.0013	.6770	.00054	-.0142
1.78	2265	.0018	1.000	.0000	118.9	.0012	.6680	.00045	-.0118
2.00	2219	.0014	1.009	-.0002	129.4	.0011	.6593	.00036	-.0097
10.00	1633	-.0004	2.184	-.0010	219.7	.0004	.5879	.00001	-.0002
20.00	1418	-.0005	3.428	-.0010	243.0	.0003	.5661	.00000	.0000
20.41	1412	-.0005	3.476	-.0010	243.6	.0003	.5655	.00000	.0000
40.00	1224	-.0005	5.502	-.0009	261.6	.0002	.5447	.00000	.0000
40.83	1219	-.0005	5.580	-.0009	262.0	.0002	.5441	.00000	.0000
80.00	1051	-.0005	8.936	-.0009	276.5	.0002	.5236	.00000	.0000
100.00	999	-.0005	10.463	-.0009	280.7	.0002	.5171	.00000	.0000
200.00	851	-.0006	17.127	-.0009	292.1	.0001	.4986	.00000	.0000
300.00	773	-.0006	22.881	-.0009	297.8	.0001	.4888	.00000	.0000
500.00	683	-.0006	32.983	-.0009	304.1	.0001	.4781	.00000	.0000
800.00	608	-.0006	46.201	-.0008	309.2	.0001	.4698	.00000	.0000
1000.00	576	-.0006	54.224	-.0008	311.4	.0001	.4662	.00000	.0000
1500.00	518	-.0006	72.546	-.0008	315.0	.0001	.4604	.00000	.0000
						.0000	.0000	.00000	.0000

TABLE III. - Continued. THERMODYNAMIC DERIVATIVES AT ASSIGNED PRESSURE RATIOS FOR LIQUID AMMONIA AND LIQUID OXYGEN

(c) Continued. Chamber pressure, 600 pounds per square inch absolute; equilibrium composition during isentropic expansion

Pressure ratio, P_c/P	Temperature, T, °K	Temperature exponent, n_T	Area ratio, ε	Area-ratio exponent, n_ε	Specific impulse, I, $\frac{(lb)(sec)}{lb}$	Specific-impulse exponent, n_I	Specific heat, c_p, $(\partial h/\partial T)_P$, (cal)/(g)(°K)	$\left(\frac{\partial \ln \mathcal{M}}{\partial \ln P}\right)_T$	$\left(\frac{\partial \ln \mathcal{M}}{\partial \ln T}\right)_P$
R, 0.80; percent fuel, 47.01; O/F, 1.127									
1.00	2760	0.0125					0.8755	0.00439	-.0987
1.05	2741	.0120	2.156	0.0027	35.9	0.0046	.8653	.00417	-.0943
1.60	2580	.0080	1.008	.0005	109.8	.0038	.7831	.00254	-.0609
1.76	2542	.0072	1.000	.0000	120.3	.0037	.7659	.00223	-.0543
2.00	2493	.0061	1.011	-.0006	132.2	.0035	.7451	.00188	-.0465
10.00	1891	-.0011	2.233	-.0044	226.1	.0015	.5932	.00009	-.0027
20.00	1658	-.0016	3.531	-.0044	250.7	.0011	.5673	.00001	-.0005
20.41	1652	-.0016	3.581	-.0044	251.4	.0011	.5666	.00001	-.0004
40.00	1447	-.0018	5.712	-.0043	270.4	.0008	.5458	.00000	-.0001
40.83	1441	-.0018	5.795	-.0043	270.9	.0008	.5452	.00000	-.0001
80.00	1255	-.0018	9.356	-.0042	286.5	.0006	.5249	.00000	.0000
100.00	1197	-.0019	10.986	-.0041	291.0	.0006	.5182	.00000	.0000
200.00	1031	-.0019	18.144	-.0041	303.4	.0005	.4977	.00000	.0000
300.00	942	-.0020	24.364	-.0041	309.6	.0004	.4865	.00000	.0000
500.00	838	-.0020	35.340	-.0041	316.5	.0004	.4733	.00000	.0000
800.00	751	-.0021	49.765	-.0041	322.1	.0003	.4624	.00000	.0000
1000.00	712	-.0021	58.545	-.0041	324.5	.0003	.4576	.00000	.0000
1500.00	645	-.0022	78.642	-.0041	328.5	.0003	.4499	.00000	.0000
						.0000	.0000	.00000	.0000
R, 0.90; percent fuel, 44.09; O/F, 1.268									
1.00	2922	0.0210					1.1223	0.01041	-.2241
1.05	2905	.0206	2.138	0.0026	36.1	0.0076	1.1114	.01010	-.2185
1.60	2765	.0168	1.007	.0005	110.4	.0069	1.0129	.00747	-.1700
1.74	2736	.0160	1.000	.0000	119.8	.0068	.9919	.00696	-.1601
2.00	2690	.0147	1.013	-.0008	133.1	.0065	.9586	.00619	-.1449
10.00	2135	-.0001	2.304	-.0095	229.6	.0038	.6391	.00069	-.0202
20.00	1896	-.0030	3.674	-.0109	255.4	.0029	.5800	.00015	-.0050
20.41	1889	-.0031	3.726	-.0109	256.1	.0028	.5788	.00015	-.0048
40.00	1670	-.0040	5.982	-.0111	276.2	.0022	.5490	.00002	-.0009
40.83	1663	-.0040	6.071	-.0111	276.7	.0022	.5483	.00002	-.0008
80.00	1462	-.0043	9.869	-.0109	293.2	.0017	.5270	.00000	-.0001
100.00	1399	-.0044	11.616	-.0109	298.1	.0016	.5203	.00000	-.0001
200.00	1217	-.0046	19.337	-.0107	311.4	.0013	.5001	.00000	.0000
300.00	1118	-.0047	26.094	-.0107	318.1	.0011	.4882	.00000	.0000
500.00	1003	-.0049	38.086	-.0107	325.6	.0009	.4737	.00000	.0000
800.00	904	-.0050	53.938	-.0107	331.7	.0008	.4611	.00000	.0000
1000.00	860	-.0051	63.621	-.0107	334.4	.0008	.4555	.00000	.0000
1500.00	784	-.0052	85.855	-.0107	338.8	.0007	.4458	.00000	.0000
						.0000	.0000	.00000	.0000
R, 0.95; percent fuel, 42.76; O/F, 1.339									
1.00	2963	0.0238					1.2294	0.01339	-.2843
1.05	2948	.0235	2.133	0.0021	35.9	0.0085	1.2208	.01309	-.2793
1.60	2815	.0204	1.006	.0004	110.1	.0080	1.1408	.01053	-.2356
1.74	2790	.0198	1.000	.0000	119.1	.0079	1.1240	.01004	-.2269
2.00	2746	.0187	1.014	-.0006	132.8	.0077	1.0946	.00923	-.2119
10.00	2241	.0034	2.348	-.0099	230.0	.0053	.7248	.00188	-.0531
20.00	2012	-.0024	3.772	-.0135	256.4	.0042	.6138	.00053	-.0167
20.41	2005	-.0025	3.826	-.0135	257.1	.0041	.6115	.00051	-.0161
40.00	1784	-.0051	6.170	-.0148	277.8	.0032	.5578	.00010	-.0036
40.83	1778	-.0052	6.262	-.0148	278.3	.0032	.5567	.00010	-.0034
80.00	1570	-.0060	10.812	-.0149	295.4	.0025	.5297	.00001	-.0005
100.00	1505	-.0061	12.031	-.0148	300.4	.0023	.5225	.00001	-.0003
200.00	1315	-.0064	20.099	-.0147	314.2	.0019	.5019	.00000	.0000
300.00	1212	-.0066	27.182	-.0146	321.2	.0017	.4903	.00000	.0000
500.00	1091	-.0068	39.792	-.0146	329.0	.0014	.4755	.00000	.0000
800.00	987	-.0070	56.511	-.0146	335.4	.0012	.4624	.00000	.0000
1000.00	940	-.0071	66.746	-.0146	338.2	.0012	.4564	.00000	.0000
1500.00	859	-.0072	90.290	-.0146	342.8	.0010	.4460	.00000	.0000
R, 0.975; percent fuel, 42.13; O/F, 1.374									
1.00	2975	0.0246					1.2570	0.01433	-.3027
1.05	2960	.0243	2.131	0.0019	35.8	0.0088	1.2494	.01404	-.2981
1.60	2829	.0214	1.006	.0003	109.8	.0083	1.1792	.01159	-.2578
1.74	2804	.0209	1.000	.0000	118.7	.0082	1.1647	.01113	-.2499
2.00	2761	.0199	1.014	-.0006	132.5	.0080	1.1390	.01035	-.2361
10.00	2280	.0065	2.367	-.0087	229.8	.0059	.8037	.00303	-.0841
20.00	2064	-.0003	3.825	-.0131	256.4	.0048	.6626	.00110	-.0338
20.41	2058	-.0005	3.881	-.0132	257.1	.0048	.6591	.00106	-.0327
40.00	1843	-.0050	6.285	-.0160	278.1	.0038	.5737	.00024	-.0084
40.83	1836	-.0051	6.379	-.0160	278.7	.0038	.5719	.00023	-.0080
80.00	1627	-.0068	10.425	-.0167	296.0	.0030	.5334	.00004	-.0014
100.00	1561	-.0070	12.290	-.0166	301.1	.0028	.5251	.00002	-.0007
200.00	1367	-.0075	20.564	-.0165	315.2	.0023	.5032	.00000	-.0001
300.00	1262	-.0076	27.839	-.0164	322.3	.0020	.4916	.00000	.0000
500.00	1138	-.0079	40.811	-.0164	330.3	.0017	.4768	.00000	.0000
800.00	1031	-.0081	58.039	-.0164	336.9	.0015	.4636	.00000	.0000
1000.00	983	-.0082	68.596	-.0164	339.7	.0014	.4575	.00000	.0000
1500.00	900	-.0084	92.907	-.0164	344.5	.0012	.4468	.00000	.0000

TABLE III. - Continued. THERMODYNAMIC DERIVATIVES AT ASSIGNED PRESSURE RATIOS FOR LIQUID AMMONIA AND LIQUID OXYGEN

(c) Continued. Chamber pressure, 600 pounds per square inch absolute; equilibrium composition during isentropic expansion

Pressure ratio, P_c/P	Temperature, T, °K	Temperature exponent, n_T	Area ratio, ϵ	Area-ratio exponent, n_ϵ	Specific impulse, I, $\frac{(lb)(sec)}{lb}$	Specific-impulse exponent, n_I	Specific heat, c_p, $(\partial h/\partial T)_p$, (cal)/(g)(°K)	$\left(\frac{\partial \ln \mathcal{M}}{\partial \ln P}\right)_T$	$\left(\frac{\partial \ln \mathcal{M}}{\partial \ln T}\right)_p$
R, 1.00; percent fuel, 41.51; O/F, 1.409									
1.00	2980	0.0249					1.2619	0.01473	-.3102
1.05	2965	.0246	2.131	0.0018	35.7	0.0089	1.2547	.01444	-.3057
1.60	2836	.0218	1.006	.0003	109.5	.0084	1.1885	.01203	-.2667
1.74	2811	.0213	1.000	.0000	118.3	.0083	1.1750	.01159	-.2591
2.00	2768	.0203	1.014	-.0005	132.0	.0081	1.1510	.01082	-.2458
10.00	2297	.0083	2.375	-.0077	229.2	.0061	.8538	.00384	-.1054
20.00	2094	.0028	3.857	-.0112	255.8	.0052	.7326	.00197	-.0594
20.41	2088	.0026	3.914	-.0113	256.5	.0052	.7294	.00193	-.0582
40.00	1888	-.0022	6.387	-.0144	277.7	.0044	.6340	.00082	-.0276
40.83	1882	-.0024	6.484	-.0145	278.3	.0043	.6315	.00080	-.0268
80.00	1684	-.0058	10.670	-.0166	295.9	.0036	.5650	.00027	-.0100
100.00	1619	-.0066	12.600	-.0171	301.1	.0033	.5490	.00018	-.0068
200.00	1425	-.0081	21.162	-.0178	315.5	.0027	.5119	.00004	-.0017
300.00	1318	-.0086	28.690	-.0179	322.9	.0024	.4963	.00001	-.0006
500.00	1191	-.0090	42.126	-.0180	331.1	.0020	.4798	.00000	-.0002
800.00	1082	-.0093	59.993	-.0180	337.9	.0018	.4658	.00000	.0000
1000.00	1032	-.0094	70.953	-.0180	340.8	.0017	.4595	.00000	.0000
1500.00	947	-.0096	96.219	-.0181	345.7	.0015	.4485	.00000	.0000
R, 1.10; percent fuel, 39.22; O/F, 1.550									
1.00	2962	0.0231					1.1481	0.01272	-.2692
1.05	2946	.0227	2.133	0.0021	35.1	0.0082	1.1398	.01242	-.2643
1.60	2812	.0196	1.006	.0004	107.6	.0077	1.0656	.00991	-.2215
1.74	2786	.0190	1.000	.0000	116.4	.0076	1.0505	.00945	-.2132
2.00	2742	.0179	1.014	-.0006	129.7	.0074	1.0246	.00868	-.1992
10.00	2245	.0051	2.355	-.0081	224.7	.0052	.7419	.00236	-.0676
20.00	2031	.0005	3.806	-.0109	250.6	.0043	.6513	.00110	-.0352
20.41	2024	.0004	3.861	-.0110	251.3	.0043	.6490	.00107	-.0345
40.00	1819	-.0029	6.274	-.0129	271.7	.0035	.5836	.00044	-.0161
40.83	1813	-.0030	6.369	-.0130	272.3	.0035	.5820	.00043	-.0157
80.00	1615	-.0051	10.451	-.0142	289.3	.0028	.5356	.00015	-.0062
100.00	1551	-.0056	12.333	-.0144	294.3	.0026	.5234	.00010	-.0044
200.00	1362	-.0066	20.676	-.0148	308.1	.0021	.4923	.00003	-.0013
300.00	1258	-.0070	28.004	-.0149	315.2	.0019	.4779	.00001	-.0005
500.00	1134	-.0073	41.063	-.0150	323.1	.0016	.4618	.00000	-.0002
800.00	1028	-.0076	58.399	-.0150	329.5	.0014	.4483	.00000	.0000
1000.00	980	-.0077	69.021	-.0150	332.3	.0013	.4424	.00000	.0000
1500.00	898	-.0079	93.482	-.0151	337.0	.0012	.4320	.00000	.0000
						.0000	.0000	.00000	.0000
R, 1.20; percent fuel, 37.16; O/F, 1.691									
1.00	2914	0.0205					1.0323	0.01016	-.2198
1.05	2898	.0201	2.136	0.0020	34.4	0.0073	1.0248	.00989	-.2154
1.60	2761	.0170	1.007	.0003	105.4	.0068	.9596	.00775	-.1779
1.74	2733	.0164	1.000	.0000	114.2	.0067	.9464	.00735	-.1706
2.00	2689	.0154	1.013	-.0006	127.1	.0065	.9249	.00673	-.1591
10.00	2182	.0041	2.343	-.0072	219.9	.0045	.6953	.00183	-.0548
20.00	1968	.0002	3.779	-.0096	245.1	.0037	.6184	.00086	-.0289
20.41	1962	.0001	3.834	-.0096	245.8	.0037	.6163	.00084	-.0283
40.00	1758	-.0028	6.218	-.0113	265.7	.0030	.5580	.00035	-.0131
40.83	1752	-.0028	6.312	-.0114	266.2	.0030	.5564	.00034	-.0128
80.00	1556	-.0046	10.337	-.0124	282.7	.0024	.5141	.00011	-.0049
100.00	1494	-.0051	12.190	-.0126	287.5	.0022	.5028	.00008	-.0034
200.00	1308	-.0059	20.395	-.0129	300.9	.0018	.4742	.00002	-.0009
300.00	1206	-.0062	27.591	-.0130	307.7	.0016	.4609	.00001	-.0004
500.00	1086	-.0065	40.395	-.0130	315.3	.0014	.4457	.00000	-.0001
800.00	983	-.0067	57.370	-.0130	321.5	.0012	.4331	.00000	.0000
1000.00	937	-.0068	67.761	-.0131	324.2	.0011	.4275	.00000	.0000
1500.00	856	-.0069	91.669	-.0131	328.7	.0010	.4178	.00000	.0000
R, 1.50; percent fuel, 32.12; O/F, 2.114									
1.00	2759	0.0157					0.8534	0.00633	-.1478
1.05	2743	.0154	2.141	0.0018	32.6	0.0058	.8478	.00615	-.1445
1.60	2603	.0128	1.007	.0003	99.7	.0053	.7989	.00473	-.1178
1.75	2574	.0122	1.000	.0000	108.3	.0052	.7887	.00446	-.1125
2.00	2530	.0114	1.013	-.0005	120.2	.0051	.7729	.00407	-.1046
10.00	2017	.0021	2.315	-.0060	207.4	.0033	.5962	.00098	-.0324
20.00	1803	-.0008	3.711	-.0078	230.8	.0027	.5367	.00042	-.0155
20.41	1797	-.0009	3.764	-.0079	231.4	.0027	.5352	.00041	-.0151
40.00	1596	-.0028	6.066	-.0090	249.8	.0021	.4920	.00014	-.0061
40.83	1591	-.0028	6.156	-.0090	250.3	.0021	.4909	.00014	-.0059
80.00	1401	-.0039	10.018	-.0095	265.4	.0017	.4598	.00004	-.0019
100.00	1341	-.0041	11.790	-.0096	269.8	.0016	.4516	.00002	-.0012
200.00	1166	-.0045	19.610	-.0097	282.0	.0013	.4303	.00000	-.0003
300.00	1071	-.0047	26.441	-.0097	289.2	.0011	.4194	.00000	-.0001
500.00	959	-.0048	38.555	-.0097	295.1	.0009	.4071	.00000	.0000
800.00	865	-.0050	54.560	-.0097	300.6	.0008	.3966	.00000	.0000
1000.00	822	-.0050	64.332	-.0097	303.0	.0008	.3918	.00000	.0000
1500.00	749	-.0051	86.765	-.0097	307.1	.0007	.3837	.00000	.0000

TABLE III. - Continued. THERMODYNAMIC DERIVATIVES AT ASSIGNED PRESSURE RATIOS FOR LIQUID AMMONIA AND LIQUID OXYGEN

(c) Concluded. Chamber pressure, 600 pounds per square inch absolute; equilibrium composition during isentropic expansion

Pressure ratio, P_c/P	Temperature, T, $^{\circ}K$	Temperature exponent, n_T	Area ratio, ϵ	Area-ratio exponent, n_ϵ	Specific impulse, I, $\frac{(lb)(sec)}{lb}$	Specific-impulse exponent, n_I	Specific heat, c_p, $(\partial h/\partial T)_P$, (cal)/(g)(°K)	$\left(\frac{\partial \ln \mathcal{M}}{\partial \ln P}\right)_T$	$\left(\frac{\partial \ln \mathcal{M}}{\partial \ln T}\right)_P$
R, 2.00; percent fuel, 26.19; O/F, 2.818									
1.00	2536	0.0110					0.6880	0.00344	-.0889
1.05	2519	.0107	2.150	0.0017	30.2	0.0042	.6833	.00332	-.0865
1.60	2377	.0084	1.008	.0003	92.4	.0038	.6421	.00241	-.0670
1.76	2345	.0078	1.000	.0000	100.8	.0037	.6330	.00224	-.0629
2.00	2302	.0071	1.011	-.0004	111.3	.0035	.6205	.00200	-.0575
10.00	1783	.0002	2.267	-.0047	191.0	.0021	.4873	.00033	-.0124
20.00	1572	-.0014	3.597	-.0056	212.1	.0016	.4495	.00011	-.0047
20.41	1566	-.0015	3.648	-.0056	212.6	.0016	.4486	.00011	-.0045
40.00	1374	-.0023	5.824	-.0059	229.0	.0012	.4224	.00003	-.0013
40.83	1369	-.0023	5.908	-.0059	229.5	.0012	.4217	.00003	-.0013
80.00	1193	-.0026	9.537	-.0060	242.8	.0009	.4028	.00001	-.0003
100.00	1138	-.0027	11.195	-.0060	246.7	.0009	.3973	.00000	-.0002
200.00	980	-.0028	18.482	-.0059	257.3	.0007	.3818	.00000	.0000
300.00	896	-.0029	24.816	-.0059	262.7	.0006	.3736	.00000	.0000
500.00	797	-.0030	35.998	-.0059	268.6	.0005	.3637	.00000	.0000
800.00	714	-.0030	50.700	-.0059	273.4	.0004	.3554	.00000	.0000
1000.00	677	-.0031	59.650	-.0059	275.5	.0004	.3517	.00000	.0000
1500.00	614	-.0031	80.136	-.0059	278.9	.0004	.3453	.00000	.0000
						.0000	.0000	.00000	.0000
R, 3.00; percent fuel, 19.13; O/F, 4.227									
1.00	2171	0.0049					0.5023	0.00102	-.0315
1.05	2154	.0047	2.170	0.0012	26.8	0.0020	.4988	.00097	-.0301
1.60	2008	.0031	1.010	.0002	81.8	.0016	.4704	.00061	-.0202
1.78	1972	.0027	1.000	.0000	90.2	.0016	.4637	.00053	-.0180
2.00	1933	.0023	1.009	-.0002	98.4	.0015	.4565	.00046	-.0159
10.00	1426	-.0005	2.186	-.0019	167.4	.0007	.3868	.00003	-.0014
20.00	1235	-.0008	3.424	-.0019	185.1	.0005	.3697	.00001	-.0003
20.41	1230	-.0008	3.471	-.0019	185.6	.0005	.3693	.00001	-.0003
40.00	1064	-.0009	5.480	-.0019	199.2	.0004	.3557	.00000	.0000
40.83	1059	-.0009	5.558	-.0019	199.6	.0004	.3553	.00000	.0000
80.00	911	-.0009	8.881	-.0019	210.5	.0003	.3434	.00000	.0000
100.00	866	-.0009	10.392	-.0019	213.7	.0003	.3395	.00000	.0000
200.00	736	-.0009	16.984	-.0018	222.3	.0002	.3282	.00000	.0000
300.00	668	-.0010	22.672	-.0018	226.7	.0002	.3220	.00000	.0000
500.00	589	-.0010	32.650	-.0018	231.4	.0001	.3148	.00000	.0000
800.00	524	-.0010	45.684	-.0018	235.2	.0001	.3089	.00000	.0000
1000.00	495	-.0010	53.587	-.0018	236.9	.0001	.3063	.00000	.0000
1500.00	446	-.0010	71.604	-.0018	239.6	.0001	.3019	.00000	.0000
						.0000	.0000	.00000	.0000
R, 4.00; percent fuel, 15.07; O/F, 5.636									
1.00	1877	0.0018					0.4111	0.00028	-.0101
1.05	1861	.0017	2.188	0.0006	24.4	0.0008	.4088	.00026	-.0095
1.60	1719	.0009	1.011	.0001	74.1	.0006	.3911	.00014	-.0054
1.80	1680	.0007	1.000	.0000	82.4	.0005	.3868	.00011	-.0045
2.00	1646	.0006	1.007	-.0001	89.1	.0005	.3831	.00009	-.0038
10.00	1179	-.0002	2.136	-.0005	150.4	.0002	.3441	.00000	-.0001
20.00	1012	-.0002	3.322	-.0005	166.0	.0001	.3322	.00000	.0000
20.41	1007	-.0002	3.367	-.0005	166.4	.0001	.3319	.00000	.0000
40.00	863	-.0003	5.280	-.0005	178.2	.0001	.3215	.00000	.0000
40.83	859	-.0003	5.354	-.0005	178.6	.0001	.3211	.00000	.0000
80.00	733	-.0003	8.497	-.0004	188.0	.0001	.3110	.00000	.0000
100.00	694	-.0003	9.920	-.0004	190.8	.0001	.3078	.00000	.0000
200.00	585	-.0003	16.099	-.0004	198.2	.0001	.2983	.00000	.0000
300.00	528	-.0003	21.402	-.0004	201.8	.0000	.2934	.00000	.0000
500.00	463	-.0003	30.665	-.0004	205.9	.0000	.2877	.00000	.0000
800.00	410	-.0003	42.718	-.0004	209.1	.0000	.2834	.00000	.0000
1000.00	386	-.0003	50.009	-.0004	210.5	.0000	.2818	.00000	.0000
1500.00	347	-.0003	66.614	-.0004	212.7	.0000	.2794	.00000	.0000
						.0000	.0000	.00000	.0000
R, 5.00; percent fuel, 12.43; O/F, 7.046									
1.00	1641	0.0006					0.3639	0.00007	-.0030
1.05	1625	.0005	2.201	0.0002	22.4	0.0003	.3625	.00007	-.0027
1.60	1491	.0002	1.013	.0000	68.1	.0002	.3515	.00003	-.0013
1.81	1454	.0002	1.000	.0000	76.1	.0002	.3487	.00002	-.0010
2.00	1424	.0001	1.006	-.0000	81.8	.0001	.3465	.00002	-.0009
10.00	1001	-.0001	2.106	-.0001	137.5	.0000	.3191	.00000	.0000
20.00	853	-.0001	3.257	-.0001	151.5	.0000	.3091	.00000	.0000
20.41	849	-.0001	3.300	-.0001	151.9	.0000	.3088	.00000	.0000
40.00	723	-.0001	5.149	-.0001	162.5	.0000	.2993	.00000	.0000
40.83	720	-.0001	5.220	-.0001	162.8	.0000	.2990	.00000	.0000
80.00	610	-.0001	8.240	-.0001	171.2	.0000	.2900	.00000	.0000
100.00	577	-.0001	9.603	-.0001	173.6	.0000	.2871	.00000	.0000
200.00	483	-.0001	15.498	-.0001	180.2	.0000	.2792	.00000	.0000
300.00	434	-.0001	20.539	-.0001	183.4	.0000	.2751	.00000	.0000
500.00	379	-.0001	29.324	-.0001	186.9	.0000	.2712	.00000	.0000
800.00	334	-.0001	40.741	-.0001	189.7	.0000	.2687	.00000	.0000
1000.00	315	-.0001	47.644	-.0001	190.9	.0000	.2677	.00000	.0000
1500.00	282	-.0001	63.355	-.0001	192.9	.0000	.2664	.00000	.0000

TABLE III. - Continued. THERMODYNAMIC DERIVATIVES AT ASSIGNED PRESSURE RATIOS FOR LIQUID AMMONIA AND LIQUID OXYGEN

(d) Chamber pressure, 600 pounds per square inch absolute; frozen composition during isentropic expansion

Pressure ratio, P_c/P	Temperature, T, °K	Temperature exponent, n_T	Area ratio, ϵ	Area-ratio exponent, n_ϵ	Specific impulse, I, $\frac{(lb)(sec)}{lb}$	Specific-impulse exponent, n_I
R, 0.40; percent fuel, 63.95; O/F, 0.564						
1.05	1334	0.0000	2.226	0.0000	29.1	0.0000
1.60	1210	.0000	1.015	.0000	88.3	.0000
2.00	1148	.0000	1.004	.0000	105.9	.0000
10.00	772	.0000	2.030	.0000	176.3	.0000
20.00	646	.0000	3.093	.0000	193.5	.0000
20.41	643	.0000	3.133	.0000	193.9	.0000
40.00	538	.0000	4.823	.0000	206.8	.0000
40.83	535	.0000	4.888	.0000	207.1	.0000
80.00	447	.0000	7.629	.0000	217.2	.0000
100.00	421	.0000	8.863	.0000	220.1	.0000
200.00	349	.0000	14.191	.0000	227.8	.0000
300.00	312	.0000	18.744	.0000	231.6	.0000
500.00	271	.0000	26.680	.0000	235.7	.0000
800.00	238	.0000	36.978	.0000	239.0	.0000
1000.00	224	.0000	43.187	.0000	240.4	.0000
1500.00	200	.0000	57.266	.0000	242.7	.0000
R, 0.50; percent fuel, 58.67; O/F, 0.705						
1.05	1766	0.0001	2.206	0.0000	32.1	0.0001
1.60	1617	.0001	1.013	.0000	97.5	.0000
2.00	1541	.0001	1.006	.0000	117.1	.0000
10.00	1074	.0001	2.090	.0000	196.4	.0000
20.00	911	.0001	3.218	.0000	216.2	.0000
20.41	906	.0001	3.261	.0000	216.8	.0000
40.00	768	.0001	5.065	.0000	231.7	.0000
40.83	764	.0001	5.134	.0000	232.1	.0000
80.00	644	.0001	8.071	.0000	243.9	.0000
100.00	608	.0001	9.595	.0000	247.3	.0000
200.00	508	.0001	15.126	.0000	256.4	.0000
300.00	456	.0001	20.032	.0000	260.9	.0000
500.00	398	.0001	28.601	.0000	265.8	.0000
800.00	351	.0001	39.755	.0000	269.8	.0000
1000.00	330	.0001	46.505	.0000	271.4	.0000
1500.00	296	.0001	61.881	.0000	274.2	.0000
R, 0.60; percent fuel, 54.19; O/F, 0.845						
1.05	2150	0.0011	2.193	0.0001	34.1	0.0005
1.60	1980	.0011	1.012	.0000	103.6	.0004
2.00	1895	.0011	1.007	.0000	124.5	.0004
10.00	1358	.0013	2.139	.0001	210.0	.0005
20.00	1166	.0013	3.329	.0002	231.8	.0005
20.41	1161	.0013	3.374	.0002	232.3	.0005
40.00	995	.0014	5.292	.0003	248.9	.0005
40.83	991	.0014	5.366	.0003	249.3	.0005
80.00	845	.0015	8.512	.0003	262.6	.0005
100.00	800	.0015	9.936	.0003	266.4	.0005
200.00	674	.0016	16.118	.0004	276.7	.0005
300.00	609	.0016	21.429	.0004	281.9	.0005
500.00	534	.0017	30.721	.0005	287.5	.0005
800.00	473	.0017	42.837	.0005	292.0	.0005
1000.00	446	.0017	50.179	.0005	293.9	.0006
1500.00	401	.0017	66.923	.0005	297.1	.0006
R, 0.70; percent fuel, 50.34; O/F, 0.986						
1.05	2481	0.0054	2.183	0.0003	35.3	0.0022
1.60	2295	.0055	1.011	.0000	107.5	.0021
2.00	2201	.0056	1.008	.0000	129.2	.0021
10.00	1611	.0064	2.176	.0006	218.9	.0023
20.00	1398	.0068	3.415	.0010	242.1	.0024
20.41	1392	.0068	3.462	.0010	242.7	.0024
40.00	1206	.0072	5.478	.0013	260.4	.0024
40.83	1201	.0072	5.556	.0013	260.9	.0024
80.00	1034	.0076	8.892	.0017	275.3	.0025
100.00	983	.0078	10.408	.0018	279.4	.0025
200.00	837	.0082	17.027	.0021	290.7	.0026
300.00	759	.0084	22.738	.0023	296.4	.0026
500.00	670	.0087	32.762	.0026	302.6	.0027
800.00	596	.0089	45.874	.0028	307.6	.0027
1000.00	564	.0090	53.831	.0028	309.8	.0027
1500.00	508	.0092	71.999	.0030	313.3	.0028

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UQ-7 back

TABLE III. - Continued. THERMODYNAMIC DERIVATIVES AT ASSIGNED PRESSURE RATIOS FOR LIQUID AMMONIA AND LIQUID OXYGEN

(d) Continued. Chamber pressure, 600 pounds per square inch absolute; frozen composition during isentropic expansion

Pressure ratio, P_c/P	Temperature, T, °K	Temperature exponent, n_T	Area ratio, ε	Area-ratio exponent, n_ε	Specific impulse, I, $\frac{(lb)(sec)}{lb}$	Specific-impulse exponent, n_I
R, 0.80; percent fuel, 47.01; O/F, 1.127						
1.05	2737	0.0137	2.176	0.0004	35.9	0.0051
1.60	2539	.0141	1.010	.0001	109.5	.0052
2.00	2440	.0143	1.009	.0001	131.7	.0053
10.00	1811	.0163	2.202	.0016	223.8	.0057
20.00	1582	.0172	3.476	.0024	247.8	.0059
20.41	1576	.0172	3.525	.0024	248.4	.0059
40.00	1376	.0183	5.612	.0033	266.9	.0060
40.83	1370	.0183	5.693	.0033	267.4	.0060
80.00	1190	.0194	9.173	.0042	282.5	.0062
100.00	1134	.0198	10.762	.0046	286.9	.0063
200.00	973	.0210	17.730	.0056	298.9	.0064
300.00	888	.0217	23.773	.0062	304.9	.0065
500.00	788	.0226	34.418	.0069	311.6	.0067
800.00	704	.0233	48.386	.0076	316.9	.0068
1000.00	667	.0236	56.880	.0078	319.2	.0068
1500.00	604	.0242	76.307	.0083	323.1	.0069
R, 0.90; percent fuel, 44.09; O/F, 1.208						
1.05	2897	0.0221	2.173	0.0007	36.0	0.0081
1.60	2693	.0227	1.010	.0001	109.9	.0082
2.00	2590	.0231	1.009	.0002	132.2	.0083
10.00	1938	.0262	2.218	.0026	225.0	.0090
20.00	1701	.0277	3.513	.0038	249.3	.0092
20.41	1694	.0278	3.562	.0039	250.0	.0093
40.00	1486	.0295	5.693	.0053	268.8	.0095
40.83	1480	.0295	5.776	.0053	269.3	.0095
80.00	1292	.0313	9.345	.0068	284.7	.0098
100.00	1234	.0320	10.979	.0074	289.2	.0099
200.00	1064	.0340	18.171	.0091	301.5	.0102
300.00	973	.0352	24.429	.0101	307.7	.0104
500.00	867	.0367	35.486	.0114	314.6	.0106
800.00	778	.0380	50.034	.0126	320.2	.0107
1000.00	738	.0386	58.894	.0131	322.6	.0108
1500.00	670	.0396	79.187	.0140	326.6	.0110
R, 0.95; percent fuel, 42.76; O/F, 1.339						
1.05	2939	0.0247	2.172	0.0007	35.9	0.0089
1.60	2733	.0255	1.010	.0002	109.5	.0091
2.00	2630	.0259	1.009	.0002	131.7	.0092
10.00	1972	.0293	2.222	.0029	224.4	.0100
20.00	1732	.0310	3.522	.0043	248.7	.0103
20.41	1726	.0311	3.572	.0043	249.4	.0103
40.00	1516	.0330	5.714	.0059	268.2	.0106
40.83	1509	.0330	5.798	.0059	268.7	.0106
80.00	1319	.0351	9.390	.0076	284.1	.0109
100.00	1260	.0358	11.037	.0082	288.6	.0110
200.00	1089	.0380	18.290	.0102	301.0	.0114
300.00	997	.0394	24.607	.0114	307.2	.0115
500.00	889	.0411	35.778	.0128	314.2	.0118
800.00	798	.0426	50.487	.0141	319.8	.0120
1000.00	758	.0433	59.451	.0148	322.2	.0121
1500.00	688	.0445	79.988	.0158	326.2	.0122

TABLE III. - Continued. THERMODYNAMIC DERIVATIVES AT ASSIGNED PRESSURE RATIOS FOR LIQUID AMMONIA AND LIQUID OXYGEN

(d) Continued. Chamber pressure, 600 pounds per square inch absolute; frozen composition during isentropic expansion

Pressure ratio, P_c/P	Temperature, T, °K	Temperature exponent, n_T	Area ratio, ε	Area-ratio exponent, $n_ε$	Specific impulse, I, $\frac{(lb)(sec)}{lb}$	Specific-impulse exponent, n_I
R, 1.00; percent fuel, 41.51; O/F, 1.409						
1.05	2956	0.0257	2.171	0.0007	35.7	0.0092
1.60	2750	.0265	1.010	.0001	108.9	.0094
2.00	2646	.0269	1.009	.0002	131.0	.0095
10.00	1986	.0305	2.223	.0030	223.1	.0103
20.00	1746	.0323	3.527	.0045	247.3	.0106
20.41	1739	.0323	3.576	.0045	247.9	.0106
40.00	1528	.0343	5.724	.0061	266.7	.0110
40.83	1522	.0343	5.808	.0062	267.2	.0110
80.00	1331	.0364	9.411	.0079	282.6	.0113
100.00	1271	.0372	11.064	.0086	287.1	.0114
200.00	1099	.0395	18.345	.0106	299.4	.0118
300.00	1007	.0410	24.691	.0118	305.6	.0119
500.00	899	.0427	35.916	.0134	312.5	.0122
800.00	807	.0443	50.704	.0148	318.1	.0124
1000.00	766	.0451	59.717	.0154	320.5	.0125
1500.00	696	.0463	80.374	.0165	324.6	.0127
R, 1.10; percent fuel, 39.22; O/F, 1.550						
1.05	2937	0.0240	2.171	0.0007	35.1	0.0086
1.60	2732	.0247	1.010	.0001	107.0	.0088
2.00	2629	.0252	1.009	.0002	128.7	.0089
10.00	1972	.0285	2.223	.0028	219.3	.0096
20.00	1733	.0302	3.525	.0042	243.0	.0099
20.41	1727	.0302	3.574	.0042	243.6	.0099
40.00	1517	.0321	5.720	.0057	262.1	.0103
40.83	1511	.0321	5.804	.0058	262.6	.0103
80.00	1321	.0341	9.403	.0075	277.6	.0106
100.00	1262	.0348	11.054	.0080	282.0	.0107
200.00	1091	.0370	18.325	.0099	294.1	.0110
300.00	999	.0383	24.661	.0111	300.2	.0112
500.00	892	.0400	35.870	.0125	307.0	.0114
800.00	801	.0415	50.634	.0138	312.5	.0116
1000.00	760	.0422	59.633	.0144	314.9	.0117
1500.00	691	.0434	80.257	.0155	318.9	.0118
R, 1.20; percent fuel, 37.16; O/F, 1.691						
1.05	2890	0.0214	2.172	0.0007	34.4	0.0079
1.60	2687	.0221	1.010	.0001	104.9	.0079
2.00	2585	.0225	1.009	.0001	126.2	.0080
10.00	1936	.0255	2.219	.0025	214.9	.0087
20.00	1700	.0270	3.517	.0038	238.1	.0089
20.41	1693	.0270	3.566	.0038	238.7	.0090
40.00	1486	.0287	5.702	.0051	256.7	.0092
40.83	1480	.0287	5.786	.0052	257.2	.0092
80.00	1293	.0305	9.366	.0067	272.0	.0095
100.00	1234	.0311	11.007	.0072	276.3	.0096
200.00	1066	.0331	18.231	.0089	288.1	.0099
300.00	976	.0343	24.522	.0099	294.0	.0100
500.00	870	.0357	35.644	.0112	300.6	.0102
800.00	781	.0371	50.287	.0123	306.0	.0104
1000.00	741	.0377	59.209	.0129	308.3	.0105
1500.00	673	.0387	79.651	.0138	312.1	.0106
R, 1.50; percent fuel, 32.12; O/F, 2.114						
1.05	2736	0.0166	2.175	0.0005	32.6	0.0062
1.60	2540	.0171	1.010	.0001	99.3	.0063
2.00	2441	.0174	1.009	.0001	119.4	.0064
10.00	1817	.0197	2.207	.0020	203.0	.0069
20.00	1590	.0209	3.488	.0029	224.8	.0071
20.41	1583	.0209	3.537	.0029	225.4	.0071
40.00	1385	.0222	5.640	.0040	242.3	.0073
40.83	1379	.0222	5.722	.0040	242.7	.0073
80.00	1201	.0235	9.236	.0051	256.5	.0075
100.00	1145	.0240	10.844	.0055	260.5	.0076
200.00	985	.0255	17.905	.0068	271.5	.0078
300.00	900	.0263	24.041	.0075	277.0	.0079
500.00	800	.0274	34.870	.0085	283.1	.0081
800.00	717	.0284	49.102	.0093	288.0	.0082
1000.00	680	.0288	57.764	.0097	290.2	.0083
1500.00	616	.0296	77.590	.0103	293.7	.0084

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TABLE III. - Concluded. THERMODYNAMIC DERIVATIVES AT ASSIGNED PRESSURE RATIOS FOR LIQUID AMMONIA AND LIQUID OXYGEN

(d) Concluded. Chamber pressure, 600 pounds per square inch absolute; frozen composition during isentropic expansion

Pressure ratio, P_c/P	Temperature, T, °K	Temperature exponent, n_T	Area ratio, ε	Area-ratio exponent, $n_ε$	Specific impulse I, $\frac{(lb)(sec)}{lb}$	Specific-impulse exponent, n_I
R, 2.00; percent fuel, 26.19; O/F, 2.818						
1.05	2513	0.0116	2.180	0.0004	30.2	0.0046
1.60	2328	.0120	1.010	.0001	92.0	.0046
2.00	2235	.0122	1.008	.0001	110.6	.0047
10.00	1646	.0138	2.188	.0013	187.7	.0050
20.00	1433	.0146	3.444	.0020	207.6	.0051
20.41	1427	.0146	3.492	.0020	208.1	.0052
40.00	1242	.0155	5.546	.0027	223.5	.0053
40.83	1237	.0155	5.626	.0027	223.9	.0053
80.00	1071	.0164	9.042	.0035	236.4	.0054
100.00	1020	.0167	10.600	.0038	240.0	.0055
200.00	873	.0177	17.426	.0046	249.9	.0056
300.00	795	.0182	23.338	.0050	254.9	.0057
500.00	704	.0189	33.746	.0056	260.4	.0058
800.00	629	.0195	47.391	.0061	264.8	.0059
1000.00	595	.0197	55.682	.0063	266.7	.0059
1500.00	538	.0202	74.630	.0067	269.9	.0060
R, 3.00; percent fuel, 19.13; O/F, 4.227						
1.05	2151	0.0053	2.189	0.0001	26.8	0.0021
1.60	1984	.0054	1.011	.0000	81.6	.0022
2.00	1900	.0055	1.007	.0000	98.1	.0022
10.00	1373	.0062	2.155	.0006	165.7	.0024
20.00	1186	.0065	3.369	.0008	183.1	.0024
20.41	1181	.0065	3.415	.0008	183.5	.0024
40.00	1019	.0069	5.385	.0011	196.8	.0025
40.83	1014	.0069	5.461	.0011	197.1	.0025
80.00	871	.0073	8.715	.0014	207.8	.0026
100.00	827	.0074	10.193	.0015	210.9	.0026
200.00	701	.0077	16.636	.0018	219.3	.0026
300.00	636	.0079	22.188	.0020	223.4	.0027
500.00	560	.0082	31.918	.0022	228.1	.0027
800.00	497	.0084	44.621	.0024	231.7	.0027
1000.00	469	.0085	52.316	.0025	233.3	.0027
1500.00	423	.0086	69.658	.0026	235.9	.0028
R, 4.00; percent fuel, 15.07; O/F, 5.636						
1.05	1859	0.0020	2.197	0.0001	24.4	0.0009
1.60	1708	.0020	1.012	.0000	74.0	.0009
2.00	1632	.0021	1.007	.0000	88.9	.0009
10.00	1162	.0023	2.127	.0002	149.8	.0009
20.00	996	.0024	3.305	.0003	165.2	.0009
20.41	991	.0024	3.350	.0003	165.6	.0009
40.00	849	.0026	5.252	.0004	177.3	.0010
40.83	845	.0026	5.325	.0004	177.6	.0010
80.00	720	.0027	8.448	.0005	187.0	.0010
100.00	682	.0027	9.861	.0005	189.7	.0010
200.00	575	.0028	15.994	.0006	197.0	.0010
300.00	519	.0029	21.257	.0007	200.7	.0010
500.00	455	.0030	30.448	.0007	204.6	.0010
800.00	402	.0030	42.406	.0008	207.8	.0010
1000.00	379	.0030	49.639	.0008	209.2	.0010
1500.00	340	.0031	66.112	.0008	211.4	.0011
R, 5.00; percent fuel, 12.43; O/F, 7.046						
1.05	1624	0.0006	2.205	0.0000	22.4	0.0003
1.60	1487	.0007	1.013	.0000	68.1	.0003
2.00	1419	.0007	1.006	.0000	81.7	.0003
10.00	996	.0007	2.103	.0001	137.3	.0003
20.00	848	.0008	3.252	.0001	151.2	.0003
20.41	844	.0008	3.295	.0001	151.6	.0003
40.00	719	.0008	5.140	.0001	162.2	.0003
40.83	715	.0008	5.212	.0001	162.4	.0003
80.00	605	.0009	8.226	.0001	170.8	.0003
100.00	573	.0009	9.585	.0002	173.3	.0003
200.00	480	.0009	15.468	.0002	179.8	.0003
300.00	431	.0009	20.497	.0002	183.0	.0003
500.00	377	.0009	29.262	.0002	186.5	.0003
800.00	332	.0009	40.653	.0002	189.3	.0003
1000.00	312	.0009	47.540	.0002	190.5	.0003
1500.00	280	.0009	63.216	.0002	192.5	.0003

TABLE IV. - EQUILIBRIUM COMPOSITION OF PRODUCTS OF REACTION AT ASSIGNED PRESSURES FOR LIQUID AMMONIA AND LIQUID OXYGEN

[Isentropic expansion from chamber conditions.]

(a) Chamber pressure, 300 pounds per square inch absolute

Static pressure, P, lb/sq in. abs	Temperature, T, °K	Mole fraction								
		H_2	H_2O	N_2	OH	O_2	NO	H	O	N
R, 0.40; percent fuel, 63.95; O/F, 0.564										
600.00	1349	0.45000	0.30000	0.25000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
571.43	1334	.45000	.30000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
375.00	1210	.45000	.30000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
326.41	1171	.45000	.30000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
300.00	1148	.45000	.30000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
60.00	772	.45000	.30000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
30.00	646	.45000	.30000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
29.39	643	.45000	.30000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
15.00	538	.45000	.30000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
14.70	535	.45000	.30000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
7.50	447	.45000	.30000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
6.00	421	.45000	.30000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
3.00	349	.45000	.30000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
2.00	312	.45000	.30000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
1.20	271	.45000	.30000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
.75	238	.45000	.30000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
.60	224	.45000	.30000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
.40	200	.45000	.30000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
R, 0.50; percent fuel, 58.87; O/F, 0.705										
600.00	1784	0.37498	0.37498	0.25000	0.00000	0.00000	0.00000	0.00003	0.00000	0.00000
571.43	1766	.37498	.37499	.25000	.00000	.00000	.00000	.00003	.00000	.00000
375.00	1617	.37500	.37500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
330.41	1574	.37500	.37500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
300.00	1542	.37500	.37500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
60.00	1075	.37500	.37500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
30.00	911	.37500	.37500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
29.39	906	.37500	.37500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
15.00	768	.37500	.37500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
14.70	764	.37500	.37500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
7.50	644	.37500	.37500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
6.00	608	.37500	.37500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
3.00	508	.37500	.37500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
2.00	456	.37500	.37500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
1.20	398	.37500	.37500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
.75	351	.37500	.37500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
.60	330	.37500	.37500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
.40	296	.37500	.37500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
R, 0.60; percent fuel, 54.19; O/F, 0.845										
600.00	2171	0.29984	0.44955	0.24991	0.00029	0.00000	0.00000	0.00041	0.00000	0.00000
571.43	2151	.29985	.44959	.24992	.00026	.00000	.00000	.00037	.00000	.00000
375.00	1983	.29993	.44985	.24997	.00009	.00000	.00000	.00016	.00000	.00000
333.38	1938	.29995	.44989	.24998	.00007	.00000	.00000	.00012	.00000	.00000
300.00	1898	.29996	.44992	.24998	.00005	.00000	.00000	.00009	.00000	.00000
60.00	1361	.30000	.45000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
30.00	1169	.30000	.45000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
29.39	1164	.30000	.45000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
15.00	998	.30000	.45000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
14.70	993	.30000	.45000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
7.50	847	.30000	.45000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
6.00	803	.30000	.45000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
3.00	676	.30000	.45000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
2.00	611	.30000	.45000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
1.20	536	.30000	.45000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
.75	474	.30000	.45000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
.60	447	.30000	.45000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
.40	402	.30000	.45000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
R, 0.70; percent fuel, 50.34; O/F, 0.986										
600.00	2503	0.22499	0.52091	0.24938	0.00277	0.00000	0.00007	0.00188	0.00000	0.00000
571.43	2483	.22497	.52122	.24942	.00255	.00000	.00006	.00176	.00000	.00000
375.00	2309	.22491	.52320	.24972	.00120	.00000	.00002	.00095	.00000	.00000
336.30	2265	.22490	.52355	.24977	.00097	.00000	.00002	.00079	.00000	.00000
300.00	2219	.22491	.52384	.24981	.00077	.00000	.00001	.00066	.00000	.00000
60.00	1633	.22499	.52498	.25000	.00000	.00000	.00000	.00002	.00000	.00000
30.00	1418	.22500	.52500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
29.39	1412	.22500	.52500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
15.00	1224	.22500	.52500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
14.70	1219	.22500	.52500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
7.50	1051	.22500	.52500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
6.00	999	.22500	.52500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
3.00	851	.22500	.52500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
2.00	773	.22500	.52500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
1.20	683	.22500	.52500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
.75	608	.22500	.52500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
.60	575	.22500	.52500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
.40	518	.22500	.52500	.25000	.00000	.00000	.00000	.00000	.00000	.00000

TABLE IV. - Continued. EQUILIBRIUM COMPOSITION OF PRODUCTS OF REACTION AT ASSIGNED PRESSURES FOR LIQUID AMMONIA AND LIQUID OXYGEN

[Isentropic expansion from chamber conditions.]

(a) Continued. Chamber pressure, 300 pounds per square inch absolute

Static pressure, P, lb/sq in. abs	Temperature, T, °K	Mole fraction								
		H_2	H_2O	N_2	OH	O_2	NO	H	O	N
R, 0.80; percent fuel, 47.01; O/F, 1.127										
300.00	2734	0.15436	0.57682	0.24692	0.01539	0.00020	0.00060	0.00559	0.00013	0.00000
285.71	2717	.15410	.57795	.24707	.01466	.00018	.00056	.00536	.00012	.00000
187.50	2563	.15227	.58639	.24820	.00914	.00008	.00029	.00359	.00005	.00000
170.41	2528	.15195	.58797	.24841	.00810	.00006	.00024	.00324	.00004	.00000
150.00	2482	.15157	.58987	.24866	.00683	.00004	.00019	.00281	.00003	.00000
30.00	1893	.15001	.59957	.24994	.00026	.00000	.00000	.00020	.00000	.00000
15.00	1661	.14999	.59994	.24999	.00004	.00000	.00000	.00004	.00000	.00000
14.70	1654	.14999	.59994	.24999	.00004	.00000	.00000	.00004	.00000	.00000
7.50	1449	.15000	.59999	.25000	.00000	.00000	.00000	.00000	.00000	.00000
7.35	1443	.15000	.59999	.25000	.00000	.00000	.00000	.00000	.00000	.00000
3.75	1257	.15000	.60000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
3.00	1199	.15000	.60000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
1.50	1033	.15000	.60000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
1.00	943	.15000	.60000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
.60	839	.15000	.60000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
.37	752	.15000	.60000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
.30	713	.15000	.60000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
.20	646	.15000	.60000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
R, 0.90; percent fuel, 44.09; O/F, 1.268										
300.00	2877	0.09462	0.61364	0.24243	0.03742	0.00180	0.00218	0.00723	0.00068	0.00000
285.71	2862	.09398	.61551	.24268	.03637	.00172	.00209	.00701	.00064	.00000
187.50	2731	.08877	.63078	.24463	.02763	.00111	.00140	.00529	.00038	.00000
172.33	2704	.08781	.63362	.24499	.02597	.00100	.00129	.00497	.00034	.00000
150.00	2661	.08630	.63813	.24556	.02332	.00084	.00110	.00448	.00027	.00000
30.00	2135	.07611	.67054	.24948	.00303	.00002	.00007	.00074	.00000	.00000
15.00	1900	.07521	.67401	.24988	.00068	.00000	.00000	.00021	.00000	.00000
14.70	1893	.07520	.67405	.24989	.00064	.00000	.00000	.00021	.00000	.00000
7.50	1675	.07502	.67485	.24998	.00010	.00000	.00000	.00004	.00000	.00000
7.35	1668	.07502	.67486	.24998	.00009	.00000	.00000	.00004	.00000	.00000
3.75	1467	.07500	.67499	.25000	.00000	.00000	.00000	.00000	.00000	.00000
3.00	1404	.07500	.67499	.25000	.00000	.00000	.00000	.00000	.00000	.00000
1.50	1221	.07500	.67500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
1.00	1122	.07500	.67500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
.60	1006	.07500	.67500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
.37	907	.07500	.67500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
.30	863	.07500	.67500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
.20	787	.07500	.67500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
R, 0.95; percent fuel, 42.76; O/F, 1.339										
300.00	2913	.07104	.62334	.23927	.05031	.00428	.00350	.00705	.00120	.00000
285.71	2899	.07024	.62544	.23954	.04922	.00416	.00339	.00685	.00115	.00000
172.91	2751	.06289	.64616	.24218	.03832	.00301	.00237	.00497	.00071	.00000
187.50	2774	.06353	.64293	.24177	.04004	.00319	.00252	.00525	.00077	.00000
150.00	2709	.06015	.65171	.24287	.03535	.00270	.00212	.00449	.00061	.00000
30.00	2234	.04185	.69970	.24858	.00829	.00027	.00029	.00097	.00004	.00000
15.00	2015	.03870	.70868	.24959	.00259	.00003	.00006	.00035	.00000	.00000
14.70	2008	.03864	.70884	.24960	.00249	.00003	.00006	.00034	.00000	.00000
7.50	1791	.03771	.71176	.24992	.00051	.00000	.00000	.00009	.00000	.00000
7.35	1784	.03770	.71180	.24992	.00049	.00000	.00000	.00009	.00000	.00000
3.75	1577	.03752	.71240	.24999	.00007	.00000	.00000	.00002	.00000	.00000
3.00	1512	.03751	.71246	.24999	.00003	.00000	.00000	.00000	.00000	.00000
1.50	1321	.03750	.71250	.25000	.00000	.00000	.00000	.00000	.00000	.00000
1.00	1218	.03750	.71250	.25000	.00000	.00000	.00000	.00000	.00000	.00000
.60	1096	.03750	.71250	.25000	.00000	.00000	.00000	.00000	.00000	.00000
.37	992	.03750	.71250	.25000	.00000	.00000	.00000	.00000	.00000	.00000
.30	945	.03750	.71250	.25000	.00000	.00000	.00000	.00000	.00000	.00000
.20	864	.03750	.71250	.25000	.00000	.00000	.00000	.00000	.00000	.00000

TABLE IV. - Continued. EQUILIBRIUM COMPOSITION OF PRODUCTS OF REACTION AT ASSIGNED PRESSURES FOR LIQUID AMMONIA AND LIQUID OXYGEN

[Isentropic expansion from chamber conditions.]

(a) Continued. Chamber pressure, 300 pounds per square inch absolute

Static pressure, P, lb/sq in. abs	Temperature, T, °K	Mole fraction								
		H_2	H_2O	N_2	OH	O_2	NO	H	O	N
R, 1.00; percent fuel, 41.51; O/F, 1.409										
300.00	2928	0.05250	0.62756	0.23558	0.06227	0.00882	0.00508	0.00636	0.00181	0.00000
285.71	2914	.05163	.62973	.23586	.06119	.00871	.00496	.00617	.00175	.00000
187.50	2792	.04425	.64799	.23820	.05197	.00767	.00398	.00466	.00128	.00000
173.12	2769	.04288	.65135	.23862	.05026	.00747	.00381	.00440	.00120	.00000
150.00	2728	.04045	.65730	.23936	.04724	.00712	.00351	.00396	.00106	.00000
30.00	2283	.01651	.71388	.24608	.01821	.00326	.00111	.00079	.00018	.00000
15.00	2089	.00912	.73049	.24792	.00968	.00191	.00055	.00027	.00006	.00000
14.70	2083	.00894	.73090	.24797	.00947	.00187	.00053	.00026	.00005	.00000
7.50	1891	.00413	.74139	.24910	.00416	.00092	.00022	.00007	.00001	.00000
7.35	1885	.00402	.74163	.24913	.00404	.00090	.00021	.00006	.00001	.00000
3.75	1691	.00144	.74708	.24970	.00136	.00035	.00007	.00001	.00000	.00000
3.00	1627	.00096	.74806	.24980	.00088	.00024	.00004	.00000	.00000	.00000
1.50	1434	.00022	.74956	.24996	.00019	.00006	.00000	.00000	.00000	.00000
1.00	1326	.00008	.74984	.24998	.00006	.00002	.00000	.00000	.00000	.00000
.60	1199	.00002	.74996	.25000	.00001	.00000	.00000	.00000	.00000	.00000
.37	1089	.00000	.74999	.25000	.00000	.00000	.00000	.00000	.00000	.00000
.30	1039	.00000	.75000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
.20	953	.00000	.75000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
R, 1.10; percent fuel, 39.22; O/F, 1.550										
300.00	2913	0.02924	0.62393	0.22740	0.07844	0.02527	0.00830	0.00452	0.00291	0.00000
285.71	2898	.02849	.62596	.22768	.07726	.02530	.00815	.00436	.00282	.00000
187.50	2773	.02230	.64284	.22994	.06712	.02560	.00695	.00309	.00216	.00000
172.87	2749	.02117	.64596	.23035	.06518	.02568	.00673	.00288	.00205	.00000
150.00	2707	.01926	.65129	.23106	.06182	.02583	.00637	.00252	.00185	.00000
30.00	2236	.00406	.69867	.23728	.02678	.02954	.00296	.00031	.00040	.00000
15.00	2030	.00142	.71045	.23890	.01525	.03188	.00188	.00007	.00015	.00000
14.70	2023	.00137	.71072	.23894	.01496	.03195	.00185	.00007	.00014	.00000
7.50	1823	.00036	.71745	.23995	.00723	.03390	.00106	.00001	.00004	.00000
7.35	1817	.00035	.71759	.23997	.00705	.03395	.00104	.00001	.00004	.00000
3.75	1621	.00006	.72093	.24053	.00275	.03520	.00051	.00000	.00000	.00000
3.00	1557	.00003	.72154	.24065	.00191	.03547	.00039	.00000	.00000	.00000
1.50	1368	.00000	.72254	.24086	.00051	.03594	.00015	.00000	.00000	.00000
1.00	1264	.00000	.72275	.24091	.00021	.03605	.00008	.00000	.00000	.00000
.60	1140	.00000	.72285	.24095	.00006	.03611	.00003	.00000	.00000	.00000
.37	1034	.00000	.72288	.24096	.00001	.03614	.00001	.00000	.00000	.00000
.30	986	.00000	.72289	.24096	.00000	.03614	.00000	.00000	.00000	.00000
.20	903	.00000	.72289	.24096	.00000	.03614	.00000	.00000	.00000	.00000
R, 1.20; percent fuel, 37.16; O/F, 1.691										
300.00	2871	0.01774	0.61255	0.21929	0.08430	0.04886	0.01073	0.00307	0.00346	0.00000
285.71	2856	.01719	.61437	.21956	.08295	.04909	.01055	.00294	.00336	.00000
187.50	2726	.01882	.62939	.22176	.07129	.05118	.00903	.00198	.00253	.00000
172.57	2701	.01204	.63220	.22218	.06901	.05162	.00875	.00182	.00238	.00000
150.00	2659	.01078	.63682	.22285	.06517	.05238	.00828	.00157	.00215	.00000
30.00	2175	.00187	.67751	.22894	.02573	.06174	.00367	.00015	.00040	.00000
15.00	1968	.00060	.68747	.23055	.01382	.06517	.00223	.00003	.00013	.00000
14.70	1962	.00058	.68769	.23059	.01353	.06526	.00219	.00003	.00013	.00000
7.50	1762	.00014	.69333	.23159	.00613	.06758	.00119	.00000	.00003	.00000
7.35	1756	.00013	.69346	.23161	.00597	.06763	.00117	.00000	.00003	.00000
3.75	1568	.00002	.69619	.23216	.00216	.06892	.00055	.00000	.00000	.00000
3.00	1499	.00001	.69667	.23227	.00146	.06918	.00041	.00000	.00000	.00000
1.50	1314	.00000	.69743	.23246	.00036	.06960	.00015	.00000	.00000	.00000
1.00	1212	.00000	.69758	.23251	.00013	.06969	.00007	.00000	.00000	.00000
.60	1091	.00000	.69765	.23254	.00003	.06975	.00003	.00000	.00000	.00000
.37	988	.00000	.69767	.23255	.00000	.06976	.00000	.00000	.00000	.00000
.30	941	.00000	.69767	.23256	.00000	.06976	.00000	.00000	.00000	.00000
.20	861	.00000	.69767	.23256	.00000	.06977	.00000	.00000	.00000	.00000
R, 1.50; percent fuel, 32.12; O/F, 2.114										
300.00	2728	0.00582	0.57156	0.19856	0.07648	0.12967	0.01364	0.00106	0.00321	0.00000
285.71	2712	.00560	.57299	.19883	.07490	.13023	.01337	.00101	.00309	.00000
187.50	2579	.00387	.58473	.20100	.06154	.13499	.01112	.00061	.00215	.00000
172.00	2551	.00357	.58698	.20142	.05889	.13593	.01068	.00055	.00198	.00000
150.00	2509	.00312	.59045	.20206	.05477	.13741	.01000	.00045	.00174	.00000
30.00	2013	.00036	.62014	.20776	.01655	.15131	.00366	.00002	.00020	.00000
15.00	1804	.00009	.62649	.20912	.00754	.15473	.00198	.00000	.00005	.00000
14.70	1798	.00008	.62662	.20916	.00734	.15481	.00194	.00000	.00005	.00000
7.50	1600	.00001	.62975	.20992	.00274	.15664	.00092	.00000	.00000	.00000
7.35	1594	.00001	.62982	.20993	.00265	.15668	.00090	.00000	.00000	.00000
3.75	1405	.00000	.63108	.21031	.00076	.15749	.00036	.00000	.00000	.00000
3.00	1345	.00000	.63127	.21037	.00047	.15763	.00026	.00000	.00000	.00000
1.50	1170	.00000	.63152	.21048	.00009	.15783	.00008	.00000	.00000	.00000
1.00	1075	.00000	.63156	.21051	.00003	.15787	.00003	.00000	.00000	.00000
.60	963	.00000	.63158	.21052	.00000	.15789	.00001	.00000	.00000	.00000
.37	868	.00000	.63158	.21052	.00000	.15789	.00000	.00000	.00000	.00000
.30	825	.00000	.63158	.21053	.00000	.15789	.00000	.00000	.00000	.00000
.20	752	.00000	.63158	.21053	.00000	.15789	.00000	.00000	.00000	.00000

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TABLE IV. - Continued. EQUILIBRIUM COMPOSITION OF PRODUCTS OF REACTION AT ASSIGNED PRESSURES FOR LIQUID AMMONIA AND LIQUID OXYGEN

[Isentropic expansion from chamber conditions.]

(a) Concluded. Chamber pressure, 300 pounds per square inch absolute

Static pressure, P, lb/sq in. abs	Temperature, T, °K	Mole fraction								
		H_2	H_2O	N_2	OH	O_2	NO	H	O	N
R, 2.00; percent fuel, 26.19; O/F, 2.818										
300.00	2515	0.00146	0.51070	0.17289	0.05063	0.24976	0.01261	0.00023	0.00171	0.00000
285.71	2499	.00139	.51176	.17313	.04919	.25041	.01229	.00021	.00162	.00000
187.50	2362	.00085	.52015	.17508	.03749	.25563	.00970	.00011	.00099	.00000
171.00	2332	.00076	.52182	.17547	.03513	.25668	.00918	.00009	.00088	.00000
150.00	2290	.00064	.52408	.17601	.03190	.25812	.00846	.00007	.00074	.00000
30.00	1782	.00003	.54155	.18041	.00605	.26966	.00226	.00000	.00004	.00000
15.00	1574	.00000	.54413	.18122	.00206	.27157	.00101	.00000	.00000	.00000
14.70	1568	.00000	.54418	.18124	.00199	.27160	.00098	.00000	.00000	.00000
7.50	1377	.00000	.54512	.18161	.00053	.27237	.00038	.00000	.00000	.00000
7.35	1371	.00000	.54513	.18161	.00051	.27238	.00036	.00000	.00000	.00000
3.75	1195	.00000	.54539	.18176	.00010	.27264	.00011	.00000	.00000	.00000
3.00	1141	.00000	.54542	.18178	.00005	.27267	.00007	.00000	.00000	.00000
1.50	982	.00000	.54545	.18181	.00000	.27272	.00002	.00000	.00000	.00000
1.00	898	.00000	.54545	.18182	.00000	.27272	.00000	.00000	.00000	.00000
.60	799	.00000	.54545	.18182	.00000	.27273	.00000	.00000	.00000	.00000
.37	716	.00000	.54545	.18182	.00000	.27273	.00000	.00000	.00000	.00000
.30	679	.00000	.54545	.18182	.00000	.27273	.00000	.00000	.00000	.00000
.20	616	.00000	.54545	.18182	.00000	.27273	.00000	.00000	.00000	.00000
R, 3.00; percent fuel, 19.13; O/F, 4.227										
300.00	2163	0.00013	0.41769	0.13859	0.01754	0.41852	0.00722	0.00001	0.00030	0.00000
285.71	2146	.00012	.41820	.13875	.01673	.41895	.00695	.00001	.00028	.00000
187.50	2004	.00005	.42197	.14002	.01072	.42223	.00489	.00000	.00012	.00000
168.77	1969	.00004	.42274	.14029	.00948	.42290	.00444	.00000	.00010	.00000
150.00	1929	.00003	.42352	.14057	.00822	.42360	.00398	.00000	.00008	.00000
30.00	1427	.00000	.42822	.14256	.00057	.42809	.00055	.00000	.00000	.00000
15.00	1236	.00000	.42850	.14277	.00011	.42845	.00017	.00000	.00000	.00000
14.70	1231	.00000	.42851	.14277	.00011	.42845	.00016	.00000	.00000	.00000
7.50	1065	.00000	.42856	.14284	.00001	.42855	.00004	.00000	.00000	.00000
7.35	1060	.00000	.42856	.14284	.00001	.42855	.00004	.00000	.00000	.00000
3.75	912	.00000	.42857	.14285	.00000	.42857	.00000	.00000	.00000	.00000
3.00	866	.00000	.42857	.14286	.00000	.42857	.00000	.00000	.00000	.00000
1.50	737	.00000	.42857	.14286	.00000	.42657	.00000	.00000	.00000	.00000
1.00	668	.00000	.42857	.14286	.00000	.42857	.00000	.00000	.00000	.00000
.60	590	.00000	.42857	.14286	.00000	.42857	.00000	.00000	.00000	.00000
.37	524	.00000	.42857	.14286	.00000	.42857	.00000	.00000	.00000	.00000
.30	495	.00000	.42857	.14286	.00000	.42857	.00000	.00000	.00000	.00000
.20	446	.00000	.42857	.14286	.00000	.42857	.00000	.00000	.00000	.00000
R, 4.00; percent fuel, 15.07; O/F, 5.636										
300.00	1875	0.00001	0.34989	0.11579	0.00515	0.52571	0.00341	0.00000	0.00004	0.00000
285.71	1858	.00000	.35009	.11588	.00481	.52593	.00324	.00000	.00003	.00000
187.50	1717	.00000	.35144	.11656	.00255	.52742	.00201	.00000	.00001	.00000
166.91	1680	.00000	.35170	.11671	.00211	.52773	.00175	.00000	.00000	.00000
150.00	1645	.00000	.35191	.11683	.00175	.52797	.00153	.00000	.00000	.00000
30.00	1179	.00000	.35291	.11759	.00005	.52934	.00011	.00000	.00000	.00000
15.00	1012	.00000	.35294	.11763	.00000	.52940	.00002	.00000	.00000	.00000
14.70	1007	.00000	.35294	.11764	.00000	.52940	.00002	.00000	.00000	.00000
7.50	864	.00000	.35294	.11765	.00000	.52941	.00000	.00000	.00000	.00000
7.35	859	.00000	.35294	.11765	.00000	.52941	.00000	.00000	.00000	.00000
3.75	733	.00000	.35294	.11765	.00000	.52941	.00000	.00000	.00000	.00000
3.00	695	.00000	.35294	.11765	.00000	.52941	.00000	.00000	.00000	.00000
1.50	585	.00000	.35294	.11765	.00000	.52941	.00000	.00000	.00000	.00000
1.00	528	.00000	.35294	.11765	.00000	.52941	.00000	.00000	.00000	.00000
.60	463	.00000	.35294	.11765	.00000	.52941	.00000	.00000	.00000	.00000
.37	410	.00000	.35294	.11765	.00000	.52941	.00000	.00000	.00000	.00000
.30	386	.00000	.35294	.11765	.00000	.52941	.00000	.00000	.00000	.00000
.20	347	.00000	.35294	.11765	.00000	.52941	.00000	.00000	.00000	.00000
R, 5.00; percent fuel, 12.43; O/F, 7.046										
300.00	1640	0.00000	0.29922	0.09923	0.00136	0.59872	0.00147	0.00000	0.00000	0.00000
285.71	1624	.00000	.29928	.09928	.00125	.59881	.00138	.00000	.00000	.00000
187.50	1491	.00000	.29968	.09961	.00055	.59940	.00076	.00000	.00000	.00000
165.69	1453	.00000	.29976	.09968	.00042	.59952	.00063	.00000	.00000	.00000
150.00	1424	.00000	.29980	.09972	.00034	.59960	.00054	.00000	.00000	.00000
30.00	1002	.00000	.30000	.09999	.00000	.59999	.00002	.00000	.00000	.00000
15.00	853	.00000	.30000	.10000	.00000	.60000	.00000	.00000	.00000	.00000
14.70	849	.00000	.30000	.10000	.00000	.60000	.00000	.00000	.00000	.00000
7.50	723	.00000	.30000	.10000	.00000	.60000	.00000	.00000	.00000	.00000
7.35	720	.00000	.30000	.10000	.00000	.60000	.00000	.00000	.00000	.00000
3.75	610	.00000	.30000	.10000	.00000	.60000	.00000	.00000	.00000	.00000
3.00	577	.00000	.30000	.10000	.00000	.60000	.00000	.00000	.00000	.00000
1.50	483	.00000	.30000	.10000	.00000	.60000	.00000	.00000	.00000	.00000
1.00	434	.00000	.30000	.10000	.00000	.60000	.00000	.00000	.00000	.00000
.60	379	.00000	.30000	.10000	.00000	.60000	.00000	.00000	.00000	.00000
.37	334	.00000	.30000	.10000	.00000	.60000	.00000	.00000	.00000	.00000
.30	315	.00000	.30000	.10000	.00000	.60000	.00000	.00000	.00000	.00000
.20	282	.00000	.30000	.10000	.00000	.60000	.00000	.00000	.00000	.00000

TABLE IV. - Continued. EQUILIBRIUM COMPOSITION OF PRODUCTS OF REACTION AT ASSIGNED PRESSURES FOR LIQUID AMMONIA AND LIQUID OXYGEN

[Isentropic expansion from chamber conditions.]

(b) Chamber pressure, 600 pounds per square inch absolute

Static pressure, P, lb/sq in. abs	Temperature, T, °K	Mole fraction								
		H_2	H_2O	N_2	OH	O_2	NO	H	O	N
R, 0.40; percent fuel, 63.95; O/F, 0.564										
300.00	1349	0.45000	0.30000	0.25000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
285.71	1334	.45000	.30000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
187.50	1210	.45000	.30000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
163.21	1171	.45000	.30000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
150.00	1148	.45000	.30000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
30.00	772	.45000	.30000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
15.00	646	.45000	.30000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
14.70	643	.45000	.30000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
7.50	538	.45000	.30000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
7.35	535	.45000	.30000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
3.75	447	.45000	.30000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
3.00	421	.45000	.30000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
1.50	349	.45000	.30000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
1.00	312	.45000	.30000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
.60	271	.45000	.30000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
.37	238	.45000	.30000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
.30	224	.45000	.30000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
.20	200	.45000	.30000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
R, 0.50; percent fuel, 58.67; O/F, 0.705										
300.00	1784	0.37497	0.37498	0.24999	0.00001	0.00000	0.00000	0.00004	0.00000	0.00000
285.71	1766	.37498	.37498	.24999	.00001	.00000	.00000	.00004	.00000	.00000
187.50	1617	.37499	.37499	.25000	.00000	.00000	.00000	.00001	.00000	.00000
165.20	1574	.37500	.37500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
150.00	1542	.37500	.37500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
30.00	1075	.37500	.37500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
15.00	911	.37500	.37500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
14.70	906	.37500	.37500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
7.50	768	.37500	.37500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
7.35	764	.37500	.37500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
3.75	644	.37500	.37500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
3.00	608	.37500	.37500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
1.50	508	.37500	.37500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
1.00	456	.37500	.37500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
.60	398	.37500	.37500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
.37	351	.37500	.37500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
.30	330	.37500	.37500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
.20	296	.37500	.37500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
R, 0.60; percent fuel, 54.19; O/F, 0.845										
300.00	2169	0.29978	0.44937	0.24987	0.00041	0.00000	0.00000	0.00057	0.00000	0.00000
285.71	2149	.29970	.44943	.24989	.00037	.00000	.00000	.00052	.00000	.00000
187.50	1982	.29990	.44979	.24996	.00013	.00000	.00000	.00022	.00000	.00000
166.72	1937	.29992	.44985	.24997	.00009	.00000	.00000	.00017	.00000	.00000
150.00	1897	.29994	.44988	.24997	.00007	.00000	.00000	.00013	.00000	.00000
30.00	1361	.30000	.45000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
15.00	1169	.30000	.45000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
14.70	1164	.30000	.45000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
7.50	998	.30000	.45000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
7.35	993	.30000	.45000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
3.75	847	.30000	.45000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
3.00	803	.30000	.45000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
1.50	676	.30000	.45000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
1.00	611	.30000	.45000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
.60	536	.30000	.45000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
.37	474	.30000	.45000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
.30	447	.30000	.45000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
.20	402	.30000	.45000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
R, 0.70; percent fuel, 50.34; O/F, 0.986										
300.00	2494	0.22497	0.51949	0.24916	0.00372	0.00000	0.00009	0.00256	0.00000	0.00000
285.71	2474	.22495	.51989	.24982	.00344	.00000	.00008	.00240	.00000	.00000
187.50	2305	.22487	.52252	.24961	.00165	.00000	.00003	.00131	.00000	.00000
168.33	2262	.22487	.52298	.24968	.00134	.00000	.00002	.00111	.00000	.00000
150.00	2216	.22487	.52339	.24974	.00107	.00000	.00002	.00091	.00000	.00000
30.00	1633	.22499	.52498	.25000	.00001	.00000	.00000	.00003	.00000	.00000
15.00	1418	.22500	.52500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
14.70	1412	.22500	.52500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
7.50	1285	.22500	.52500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
7.35	1219	.22500	.52500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
3.75	1052	.22500	.52500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
3.00	1000	.22500	.52500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
1.50	852	.22500	.52500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
1.00	773	.22500	.52500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
.60	683	.22500	.52500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
.37	608	.22500	.52500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
.30	575	.22500	.52500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
.20	519	.22500	.52500	.25000	.00000	.00000	.00000	.00000	.00000	.00000

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TABLE IV. - Continued. EQUILIBRIUM COMPOSITION OF PRODUCTS OF REACTION AT ASSIGNED PRESSURES FOR LIQUID AMMONIA AND LIQUID OXYGEN

[Isentropic expansion from chamber conditions.]

(b) Continued. Chamber pressure, 600 pounds per square inch absolute

Static pressure, P, lb/sq in. abs	Temperature, T, °K	Mole fraction								
		H_2	H_2O	N_2	OH	O_2	NO	H	O	N
R, 0.80; percent fuel, 47.01; O/F, 1.127										
600.00	2760	0.15349	0.58163	0.24756	0.01228	0.00013	0.00050	0.00433	0.00008	0.00000
571.43	2741	.15327	.58259	.24769	.01166	.00011	.00046	.00414	.00007	.00000
375.00	2580	.15175	.58958	.24862	.00704	.00005	.00023	.00271	.00003	.00000
340.01	2542	.15148	.59088	.24879	.00617	.00004	.00019	.00243	.00002	.00000
300.00	2493	.15119	.59238	.24899	.00516	.00003	.00015	.00209	.00002	.00000
60.00	1891	.15000	.59970	.24996	.00020	.00000	.00000	.00014	.00000	.00000
30.00	1658	.15000	.59996	.24999	.00003	.00000	.00000	.00003	.00000	.00000
29.39	1652	.15000	.59996	.24999	.00002	.00000	.00000	.00003	.00000	.00000
15.00	1447	.15000	.60000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
14.70	1441	.15000	.60000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
7.50	1255	.15000	.60000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
6.00	1197	.15000	.60000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
3.00	1031	.15000	.60000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
2.00	942	.15000	.60000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
1.20	838	.15000	.60000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
.75	751	.15000	.60000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
.60	712	.15000	.60000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
.40	645	.15000	.60000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
R, 0.90; percent fuel, 44.09; O/F, 1.268										
600.00	2922	0.09179	0.62276	0.24352	0.03225	0.00136	0.00201	0.00582	0.00049	0.00000
571.43	2905	.09119	.62449	.24375	.03126	.00129	.00192	.00564	.00046	.00000
375.00	2765	.08642	.63841	.24554	.02315	.00079	.00125	.00418	.00026	.00000
343.86	2736	.08553	.64103	.24587	.02160	.00070	.00113	.00391	.00023	.00000
300.00	2690	.08421	.64497	.24637	.01923	.00058	.00096	.00350	.00018	.00000
60.00	2135	.07576	.67184	.24963	.00215	.00001	.00005	.00052	.00000	.00000
30.00	1896	.07514	.67432	.24992	.00046	.00000	.00000	.00015	.00000	.00000
29.39	1889	.07513	.67436	.24992	.00044	.00000	.00000	.00014	.00000	.00000
15.00	1670	.07502	.67490	.24999	.00007	.00000	.00000	.00003	.00000	.00000
14.70	1663	.07501	.67491	.24999	.00006	.00000	.00000	.00003	.00000	.00000
7.50	1462	.07500	.67499	.25000	.00000	.00000	.00000	.00000	.00000	.00000
6.00	1399	.07500	.67500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
3.00	1217	.07500	.67500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
2.00	1118	.07500	.67500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
1.20	1003	.07500	.67500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
.75	904	.07500	.67500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
.60	860	.07500	.67500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
.40	784	.07500	.67500	.25000	.00000	.00000	.00000	.00000	.00000	.00000
R, 0.95; percent fuel, 42.76; O/F, 1.339										
600.00	2963	0.06722	0.63401	0.24046	0.04478	0.00352	0.00339	0.00569	0.00092	0.00000
571.43	2948	.06645	.63600	.24072	.04374	.00342	.00328	.00552	.00088	.00000
375.00	2815	.06004	.65247	.24284	.03498	.00254	.00239	.00417	.00057	.00000
345.19	2790	.05884	.65556	.24323	.03332	.00237	.00223	.00393	.00052	.00000
300.00	2746	.05685	.66066	.24387	.03055	.00210	.00198	.00354	.00044	.00000
60.00	2241	.04069	.70303	.24895	.00623	.00016	.00022	.00070	.00002	.00000
30.00	2012	.03832	.70986	.24971	.00180	.00002	.00004	.00024	.00000	.00000
29.39	2005	.03828	.70998	.24973	.00173	.00002	.00004	.00023	.00000	.00000
15.00	1784	.03764	.71201	.24995	.00034	.00000	.00000	.00006	.00000	.00000
14.70	1778	.03763	.71204	.24995	.00032	.00000	.00000	.00006	.00000	.00000
7.50	1570	.03752	.71244	.24999	.00004	.00000	.00000	.00001	.00000	.00000
6.00	1505	.03751	.71247	.25000	.00002	.00000	.00000	.00000	.00000	.00000
3.00	1315	.03750	.71250	.25000	.00000	.00000	.00000	.00000	.00000	.00000
2.00	1212	.03750	.71250	.25000	.00000	.00000	.00000	.00000	.00000	.00000
1.20	1091	.03750	.71250	.25000	.00000	.00000	.00000	.00000	.00000	.00000
.75	987	.03750	.71250	.25000	.00000	.00000	.00000	.00000	.00000	.00000
.60	940	.03750	.71250	.25000	.00000	.00000	.00000	.00000	.00000	.00000
.40	859	.03750	.71250	.25000	.00000	.00000	.00000	.00000	.00000	.00000
R, 0.975; percent fuel, 42.15; O/F, 1.374										
600.00	2975	0.05696	0.63721	0.23867	0.05096	0.00536	0.00423	0.00543	0.00118	0.00000
571.43	2960	.05613	.63926	.23894	.04992	.00525	.00411	.00527	.00113	.00000
375.00	2829	.04920	.65643	.24115	.04110	.00425	.00314	.00396	.00078	.00000
345.55	2804	.04789	.65964	.24155	.03943	.00406	.00297	.00373	.00072	.00000
300.00	2761	.04567	.66509	.24224	.03661	.00373	.00268	.00336	.00062	.00000
60.00	2280	.02531	.71441	.24814	.01023	.00067	.00050	.00068	.00006	.00000
30.00	2064	.02085	.72550	.24938	.00375	.00013	.00013	.00025	.00000	.00000
29.39	2058	.02077	.72572	.24941	.00361	.00012	.00013	.00024	.00000	.00000
15.00	1843	.01918	.72999	.24987	.00086	.00000	.00002	.00007	.00000	.00000
14.70	1836	.01915	.73006	.24988	.00082	.00000	.00002	.00007	.00000	.00000
7.50	1627	.01881	.73107	.24998	.00012	.00000	.00000	.00001	.00000	.00000
6.00	1561	.01878	.73116	.24999	.00006	.00000	.00000	.00000	.00000	.00000
3.00	1367	.01875	.73124	.25000	.00000	.00000	.00000	.00000	.00000	.00000
2.00	1262	.01875	.73125	.25000	.00000	.00000	.00000	.00000	.00000	.00000
1.20	1138	.01875	.73125	.25000	.00000	.00000	.00000	.00000	.00000	.00000
.75	1031	.01875	.73125	.25000	.00000	.00000	.00000	.00000	.00000	.00000
.60	983	.01875	.73125	.25000	.00000	.00000	.00000	.00000	.00000	.00000
.40	900	.01875	.73125	.25000	.00000	.00000	.00000	.00000	.00000	.00000

TABLE IV. - Continued. EQUILIBRIUM COMPOSITION OF PRODUCTS OF REACTION AT ASSIGNED PRESSURES FOR LIQUID AMMONIA AND LIQUID OXYGEN

[Isentropic expansion from chamber conditions.]

(b) Continued. Chamber pressure, 600 pounds per square inch absolute

Static pressure, P, lb/sq in. abs	Temperature, T, °K	Mole fraction								
		H_2	H_2O	N_2	OH	O_2	NO	H	O	N
R, 1.00; percent fuel, 41.51; O/F, 1.409										
600.00	2980	0.04811	0.63890	0.23674	0.05673	0.00785	0.00513	0.00508	0.00145	0.00000
571.43	2965	.04726	.64098	.23701	.05568	.00774	.00500	.00492	.00140	.00000
375.00	2836	.04010	.65839	.23926	.04685	.00676	.00398	.00366	.00101	.00000
345.69	2811	.03876	.66164	.23967	.04519	.00657	.00379	.00344	.00094	.00000
300.00	2768	.03644	.66721	.24037	.04234	.00684	.00349	.00308	.00083	.00000
60.00	2297	.01401	.71953	.24665	.01538	.00272	.00104	.00056	.00012	.00000
30.00	2094	.00746	.73412	.24829	.00788	.00154	.00050	.00018	.00004	.00000
29.39	2088	.00730	.73447	.24833	.00770	.00151	.00048	.00017	.00003	.00000
15.00	1888	.00324	.74326	.24929	.00325	.00072	.00019	.00004	.00000	.00000
14.70	1882	.00315	.74345	.24931	.00315	.00070	.00019	.00004	.00000	.00000
7.50	1684	.00109	.74779	.24977	.00102	.00026	.00006	.00000	.00000	.00000
6.00	1619	.00072	.74855	.24985	.00066	.00018	.00004	.00000	.00000	.00000
3.00	1425	.00016	.74968	.84997	.00013	.00004	.00000	.00000	.00000	.00000
2.00	1318	.00006	.74989	.24999	.00004	.00002	.00000	.00000	.00000	.00000
1.20	1191	.00001	.74998	.25000	.00000	.00000	.00000	.00000	.00000	.00000
.75	1082	.00000	.74999	.25000	.00000	.00000	.00000	.00000	.00000	.00000
.60	1032	.00000	.75000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
.40	947	.00000	.75000	.25000	.00000	.00000	.00000	.00000	.00000	.00000
R, 1.10; percent fuel, 39.22; O/F, 1.550										
600.00	2962	0.02527	0.63453	0.22826	0.07266	0.02466	0.00873	0.00347	0.00248	0.00000
571.43	2946	.02457	.63644	.22852	.07151	.02471	.00857	.00334	.00234	.00000
375.00	2812	.01883	.65224	.23070	.06166	.02519	.00730	.00231	.00177	.00000
345.11	2786	.01777	.65520	.23110	.05975	.02531	.00706	.00213	.00167	.00000
300.00	2742	.01606	.66007	.23177	.05653	.02553	.00668	.00186	.00151	.00000
60.00	2245	.00303	.70257	.23760	.02334	.02993	.00304	.00020	.00030	.00000
30.00	2031	.00101	.71263	.23909	.01294	.03229	.00190	.00004	.00011	.00000
29.39	2024	.00097	.71285	.23913	.01268	.03235	.00187	.00004	.00010	.00000
15.00	1819	.00025	.71846	.24004	.00599	.03418	.00105	.00000	.00003	.00000
14.70	1813	.00024	.71858	.24007	.00583	.03428	.00103	.00000	.00003	.00000
7.50	1615	.00004	.72132	.24057	.00223	.03534	.00050	.00000	.00000	.00000
6.00	1551	.00002	.72181	.24068	.00154	.03557	.00038	.00000	.00000	.00000
3.00	1362	.00000	.72261	.24087	.00041	.03597	.00014	.00000	.00000	.00000
2.00	1258	.00000	.72278	.24092	.00016	.03607	.00007	.00000	.00000	.00000
1.20	1134	.00000	.72286	.24095	.00004	.03612	.00003	.00000	.00000	.00000
.75	1028	.00000	.72288	.24096	.00001	.03614	.00001	.00000	.00000	.00000
.60	980	.00000	.72289	.24096	.00000	.03614	.00000	.00000	.00000	.00000
.40	898	.00000	.72289	.24096	.00000	.03614	.00000	.00000	.00000	.00000
R, 1.20; percent fuel, 37.16; O/F, 1.691										
600.00	2914	0.01485	0.62178	0.21988	0.07789	0.04905	0.01138	0.00229	0.00287	0.00000
571.43	2898	.01436	.62347	.22014	.07657	.04932	.01118	.00219	.00278	.00000
375.00	2761	.01049	.63735	.22229	.06522	.05161	.00954	.00144	.00207	.00000
344.53	2733	.00980	.63998	.22269	.06296	.05210	.00922	.00131	.00194	.00000
300.00	2689	.00872	.64416	.22334	.05930	.05290	.00872	.00112	.00174	.00000
60.00	2182	.00138	.68059	.22918	.02228	.06244	.00375	.00009	.00030	.00000
30.00	1968	.00043	.68917	.23069	.01168	.06567	.00224	.00002	.00009	.00000
29.39	1962	.00041	.68936	.23073	.01143	.06575	.00220	.00002	.00009	.00000
15.00	1758	.00010	.69412	.23166	.00507	.06786	.00118	.00000	.00002	.00000
14.70	1752	.00009	.69422	.23168	.00493	.06790	.00116	.00000	.00002	.00000
7.50	1556	.00001	.69647	.23219	.00175	.06904	.00053	.00000	.00000	.00000
6.00	1494	.00000	.69687	.23229	.00118	.06925	.00040	.00000	.00000	.00000
3.00	1308	.00000	.69748	.23247	.00028	.06962	.00014	.00000	.00000	.00000
2.00	1206	.00000	.69760	.23252	.00011	.06970	.00007	.00000	.00000	.00000
1.20	1086	.00000	.69766	.23254	.00003	.06975	.00003	.00000	.00000	.00000
.75	983	.00000	.69767	.23255	.00000	.06976	.00000	.00000	.00000	.00000
.60	937	.00000	.69767	.23256	.00000	.06976	.00000	.00000	.00000	.00000
.40	856	.00000	.69767	.23256	.00000	.06977	.00000	.00000	.00000	.00000
R, 1.50; percent fuel, 32.12; O/F, 2.114										
600.00	2759	0.00470	0.57807	0.19880	0.06956	0.13113	0.01436	0.00076	0.00259	0.00000
571.43	2743	.00451	.57940	.19906	.06805	.13171	.01407	.00071	.00249	.00000
375.00	2603	.00307	.59017	.20123	.05537	.13641	.01163	.00042	.00171	.00000
343.44	2574	.00281	.59826	.20165	.05283	.13735	.01114	.00038	.00157	.00000
300.00	2530	.00245	.59538	.20229	.04901	.13878	.01042	.00031	.00137	.00000
60.00	2017	.00026	.62188	.20789	.01414	.15198	.00370	.00001	.00015	.00000
30.00	1803	.00006	.62733	.20920	.00631	.15509	.00198	.00000	.00003	.00000
29.39	1797	.00006	.62745	.20922	.00615	.15515	.00194	.00000	.00003	.00000
15.00	1596	.00001	.63008	.20995	.00226	.15679	.00091	.00000	.00000	.00000
14.70	1591	.00000	.63013	.20997	.00218	.15682	.00089	.00000	.00000	.00000
7.50	1401	.00000	.63117	.21032	.00062	.15754	.00035	.00000	.00000	.00000
6.00	1341	.00000	.63133	.21038	.00038	.15765	.00025	.00000	.00000	.00000
3.00	1166	.00000	.63153	.21049	.00007	.15784	.00007	.00000	.00000	.00000
2.00	1071	.00000	.63157	.21051	.00002	.15787	.00003	.00000	.00000	.00000
1.20	959	.00000	.63158	.21052	.00000	.15789	.00000	.00000	.00000	.00000
.75	865	.00000	.63158	.21052	.00000	.15789	.00000	.00000	.00000	.00000
.60	822	.00000	.63158	.21053	.00000	.15789	.00000	.00000	.00000	.00000
.40	749	.00000	.63158	.21053	.00000	.15789	.00000	.00000	.00000	.00000

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TABLE IV. - Concluded. EQUILIBRIUM COMPOSITION OF PRODUCTS OF REACTION AT ASSIGNED PRESSURES FOR LIQUID AMMONIA AND LIQUID OXYGEN

[Isentropic expansion from chamber conditions.]

(b) Concluded. Chamber pressure, 600 pounds per square inch absolute

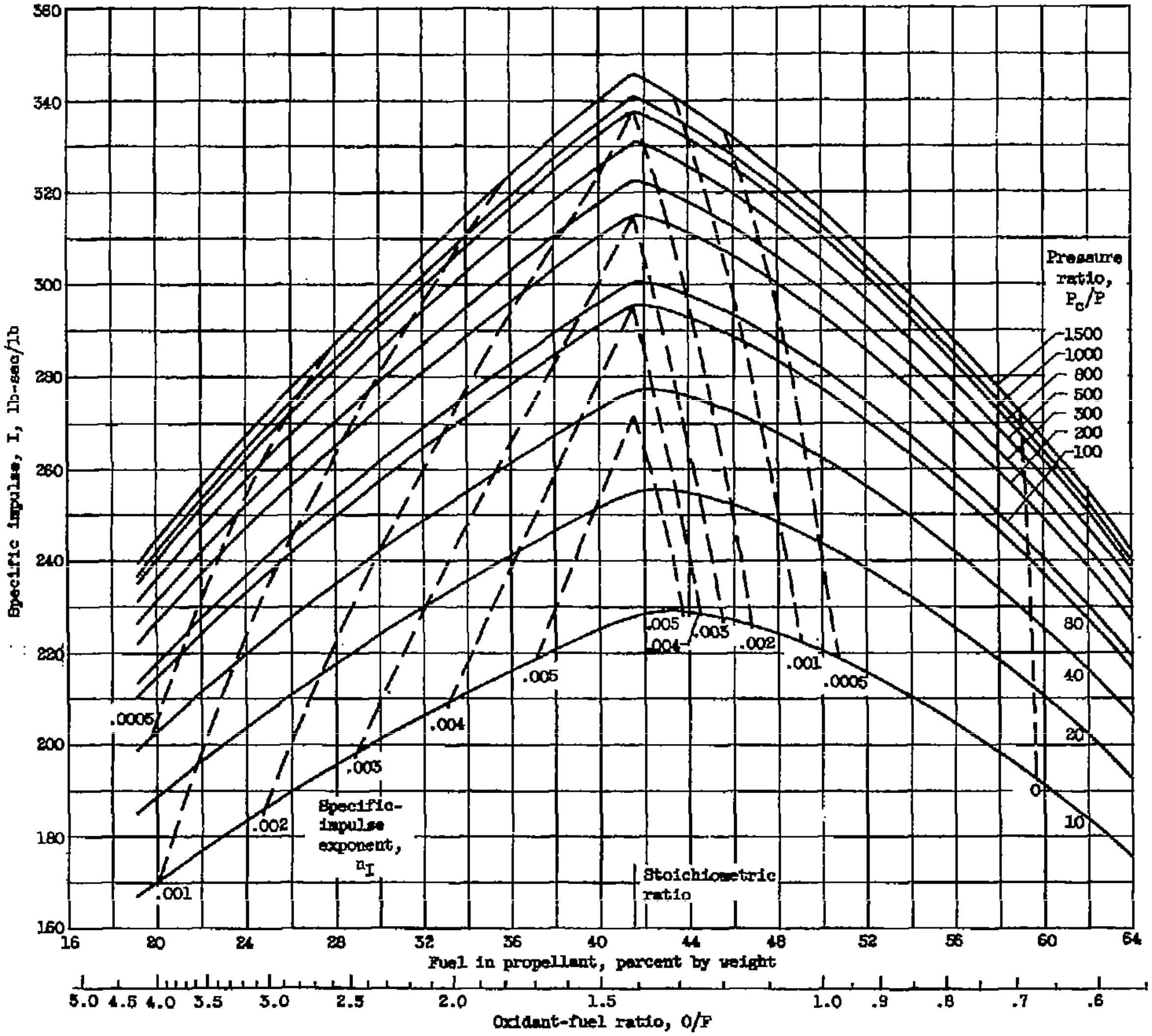
Static pressure, P, lb/sq in. abs	Temperature, T, °K	Mole fraction								
		H_2	H_2O	N_2	OH	O_2	NO	H	O	N
R, 2.00; percent fuel, 26.19; O/F, 2.818										
600.00	2536	0.00114	0.51475	0.17297	0.04516	0.25138	0.01310	0.00015	0.00134	0.00000
571.43	2519	.00108	.51571	.17321	.04383	.25200	.01276	.00014	.00127	.00000
375.00	2377	.00065	.52330	.17517	.03307	.25696	.01001	.00007	.00076	.00000
341.52	2345	.00058	.52483	.17557	.03089	.25796	.00944	.00006	.00067	.00000
300.00	2302	.00048	.52684	.17610	.02798	.25930	.00869	.00005	.00056	.00000
60.00	1783	.00002	.54217	.18045	.00510	.26997	.00226	.00000	.00003	.00000
30.00	1572	.00000	.54436	.18124	.00172	.27168	.00100	.00000	.00000	.00000
29.39	1566	.00000	.54440	.18126	.00165	.27171	.00097	.00000	.00000	.00000
15.00	1374	.00000	.54518	.18161	.00044	.27240	.00037	.00000	.00000	.00000
14.70	1369	.00000	.54519	.18162	.00042	.27241	.00036	.00000	.00000	.00000
7.50	1193	.00000	.54540	.18176	.00008	.27265	.00011	.00000	.00000	.00000
6.00	1138	.00000	.54543	.18178	.00004	.27268	.00007	.00000	.00000	.00000
3.00	980	.00000	.54545	.18181	.00000	.27272	.00002	.00000	.00000	.00000
2.00	896	.00000	.54545	.18182	.00000	.27272	.00000	.00000	.00000	.00000
1.20	797	.00000	.54545	.18182	.00000	.27273	.00000	.00000	.00000	.00000
.75	714	.00000	.54545	.18182	.00000	.27273	.00000	.00000	.00000	.00000
.60	677	.00000	.54545	.18182	.00000	.27273	.00000	.00000	.00000	.00000
.40	614	.00000	.54545	.18182	.00000	.27273	.00000	.00000	.00000	.00000
R, 3.00; percent fuel, 19.13; O/F, 4.227										
600.00	2171	0.00010	0.41917	0.13861	0.01521	0.41932	0.00736	0.00000	0.00023	0.00000
571.43	2154	.00009	.41963	.13878	.01449	.41973	.00709	.00000	.00021	.00000
375.00	2008	.00004	.42291	.14004	.00920	.42275	.00495	.00000	.00009	.00000
337.20	1972	.00003	.42359	.14031	.00812	.42338	.00449	.00000	.00007	.00000
300.00	1933	.00002	.42426	.14059	.00703	.42402	.00402	.00000	.00006	.00000
60.00	1426	.00000	.42828	.14257	.00048	.42813	.00055	.00000	.00000	.00000
30.00	1235	.00000	.42852	.14277	.00009	.42845	.00017	.00000	.00000	.00000
29.39	1230	.00000	.42852	.14277	.00009	.42846	.00016	.00000	.00000	.00000
15.00	1064	.00000	.42856	.14284	.00001	.42855	.00004	.00000	.00000	.00000
14.70	1059	.00000	.42856	.14284	.00001	.42855	.00004	.00000	.00000	.00000
7.50	911	.00000	.42857	.14285	.00000	.42857	.00000	.00000	.00000	.00000
6.00	866	.00000	.42857	.14286	.00000	.42857	.00000	.00000	.00000	.00000
3.00	736	.00000	.42857	.14286	.00000	.42857	.00000	.00000	.00000	.00000
2.00	668	.00000	.42857	.14286	.00000	.42857	.00000	.00000	.00000	.00000
1.20	589	.00000	.42857	.14286	.00000	.42857	.00000	.00000	.00000	.00000
.75	524	.00000	.42857	.14286	.00000	.42857	.00000	.00000	.00000	.00000
.60	495	.00000	.42857	.14286	.00000	.42857	.00000	.00000	.00000	.00000
.40	446	.00000	.42857	.14286	.00000	.42857	.00000	.00000	.00000	.00000
R, 4.00; percent fuel, 15.07; O/F, 5.636										
600.00	1877	0.00000	0.35035	0.11580	0.00438	0.52600	0.00344	0.00000	0.00003	0.00000
571.43	1861	.00000	.35052	.11589	.00409	.52620	.00327	.00000	.00002	.00000
375.00	1719	.00000	.35167	.11657	.00216	.52757	.00202	.00000	.00000	.00000
333.68	1680	.00000	.35189	.11672	.00178	.52785	.00175	.00000	.00000	.00000
300.00	1646	.00000	.35207	.11684	.00148	.52808	.00153	.00000	.00000	.00000
60.00	1179	.00000	.35292	.11759	.00004	.52934	.00011	.00000	.00000	.00000
30.00	1012	.00000	.35294	.11763	.00000	.52940	.00002	.00000	.00000	.00000
29.39	1007	.00000	.35294	.11764	.00000	.52940	.00002	.00000	.00000	.00000
15.00	863	.00000	.35294	.11765	.00000	.52941	.00000	.00000	.00000	.00000
14.70	859	.00000	.35294	.11765	.00000	.52941	.00000	.00000	.00000	.00000
7.50	733	.00000	.35294	.11765	.00000	.52941	.00000	.00000	.00000	.00000
6.00	694	.00000	.35294	.11765	.00000	.52941	.00000	.00000	.00000	.00000
3.00	585	.00000	.35294	.11765	.00000	.52941	.00000	.00000	.00000	.00000
2.00	528	.00000	.35294	.11765	.00000	.52941	.00000	.00000	.00000	.00000
1.20	463	.00000	.35294	.11765	.00000	.52941	.00000	.00000	.00000	.00000
.75	410	.00000	.35294	.11765	.00000	.52941	.00000	.00000	.00000	.00000
.60	386	.00000	.35294	.11765	.00000	.52941	.00000	.00000	.00000	.00000
.40	347	.00000	.35294	.11765	.00000	.52941	.00000	.00000	.00000	.00000
R, 5.00; percent fuel, 12.43; O/F, 7.046										
600.00	1641	0.00000	0.29934	0.09924	0.00115	0.59880	0.00147	0.00000	0.00000	0.00000
571.43	1625	.00000	.29939	.09928	.00105	.59889	.00138	.00000	.00000	.00000
375.00	1491	.00000	.29973	.09961	.00046	.59944	.00076	.00000	.00000	.00000
331.33	1454	.00000	.29979	.09968	.00036	.59954	.00063	.00000	.00000	.00000
300.00	1424	.00000	.29984	.09972	.00029	.59962	.00054	.00000	.00000	.00000
60.00	1001	.00000	.30000	.09999	.00000	.59999	.00002	.00000	.00000	.00000
30.00	853	.00000	.30000	.10000	.00000	.60000	.00000	.00000	.00000	.00000
29.39	849	.00000	.30000	.10000	.00000	.60000	.00000	.00000	.00000	.00000
15.00	723	.00000	.30000	.10000	.00000	.60000	.00000	.00000	.00000	.00000
14.70	720	.00000	.30000	.10000	.00000	.60000	.00000	.00000	.00000	.00000
7.50	610	.00000	.30000	.10000	.00000	.60000	.00000	.00000	.00000	.00000
6.00	577	.00000	.30000	.10000	.00000	.60000	.00000	.00000	.00000	.00000
3.00	483	.00000	.30000	.10000	.00000	.60000	.00000	.00000	.00000	.00000
2.00	434	.00000	.30000	.10000	.00000	.60000	.00000	.00000	.00000	.00000
1.20	379	.00000	.30000	.10000	.00000	.60000	.00000	.00000	.00000	.00000
.75	334	.00000	.30000	.10000	.00000	.60000	.00000	.00000	.00000	.00000
.60	315	.00000	.30000	.10000	.00000	.60000	.00000	.00000	.00000	.00000
.40	282	.00000	.30000	.10000	.00000	.60000	.00000	.00000	.00000	.00000

TABLE V. - SUMMARY OF COMBUSTION PARAMETERS, CHARACTERISTIC VELOCITY, AND PERFORMANCE FOR EXPANSION TO SEA LEVEL FOR LIQUID AMMONIA WITH LIQUID OXYGEN

Equivalence ratio, R, 2(O)/H	Fuel, percent by weight	Oxidant-to-fuel weight ratio, O/F	Combustion temperature, T_c, $^{\circ}K$	Exit temperature, T_e, $^{\circ}K$	Characteristic velocity, c^*, ft/sec	Characteristic-velocity exponent, n_{c^*}	Entropy, s, $\frac{cal}{(g)(^{\circ}K)}$	Area ratio, ε	Coefficient of thrust, C_F	Specific impulse, I, $\frac{(lb)(sec)}{lb}$
Chamber pressure, 300 pounds per square inch absolute; equilibrium composition										
0.40	63.95	0.564	1349	643	4509	0.0000	3.5155	3.133	1.384	193.9
.50	58.67	.705	1784	906	5016	.0000	3.4925	3.261	1.390	216.8
.60	54.19	.845	2169	1164	5358	.0000	3.4355	3.376	1.396	232.5
.70	50.34	.986	2494	1412	5595	.0003	3.3653	3.478	1.401	243.6
.80	47.01	1.127	2734	1654	5744	.0023	3.2910	3.594	1.407	251.2
.90	44.09	1.268	2877	1893	5799	.0057	3.2170	3.757	1.418	255.5
.95	42.76	1.339	2913	2008	5790	.0070	3.1809	3.863	1.424	256.3
1.00	41.51	1.409	2928	2083	5759	.0075	3.1454	3.945	1.428	255.6
1.10	39.22	1.550	2913	2023	5656	.0067	3.0773	3.892	1.425	250.5
1.20	37.16	1.691	2871	1962	5542	.0058	3.0134	3.861	1.423	245.1
1.50	32.12	2.114	2728	1798	5238	.0044	2.8478	3.786	1.419	231.0
2.00	26.19	2.818	2515	1568	4840	.0028	2.6410	3.663	1.412	212.4
3.00	19.13	4.227	2163	1231	4261	.0008	2.3763	3.476	1.401	185.5
4.00	15.07	5.636	1875	1007	3837	.0001	2.2111	3.368	1.395	166.4
5.00	12.43	7.046	1640	849	3510	.0000	2.0954	3.301	1.392	151.9
Chamber pressure, 300 pounds per square inch absolute; frozen composition										
0.40	63.95	0.564	1349	643	4509	0.0000	3.5155	3.133	1.384	193.9
.50	58.67	.705	1784	906	5015	.0003	3.4925	3.261	1.390	216.8
.60	54.19	.845	2169	1160	5351	.0005	3.4355	3.373	1.396	232.2
.70	50.34	.986	2494	1385	5564	.0023	3.3653	3.460	1.401	242.3
.80	47.01	1.127	2734	1557	5669	.0056	3.2910	3.519	1.404	247.4
.90	44.09	1.268	2877	1662	5685	.0086	3.2170	3.553	1.406	248.4
.95	42.76	1.339	2913	1689	5665	.0096	3.1809	3.561	1.406	247.6
1.00	41.51	1.409	2928	1700	5631	.0100	3.1454	3.565	1.406	246.1
1.10	39.22	1.550	2913	1691	5536	.0094	3.0773	3.564	1.406	241.9
1.20	37.16	1.691	2871	1662	5429	.0085	3.0134	3.557	1.406	237.2
1.50	32.12	2.114	2728	1561	5138	.0067	2.8478	3.530	1.404	224.3
2.00	26.19	2.818	2515	1413	4759	.0048	2.6410	3.487	1.402	207.4
3.00	19.13	4.227	2163	1175	4215	.0024	2.3763	3.413	1.398	183.2
4.00	15.07	5.636	1875	989	3816	.0011	2.2111	3.349	1.395	165.5
5.00	12.43	7.046	1640	844	3502	.0004	2.0954	3.295	1.392	151.6

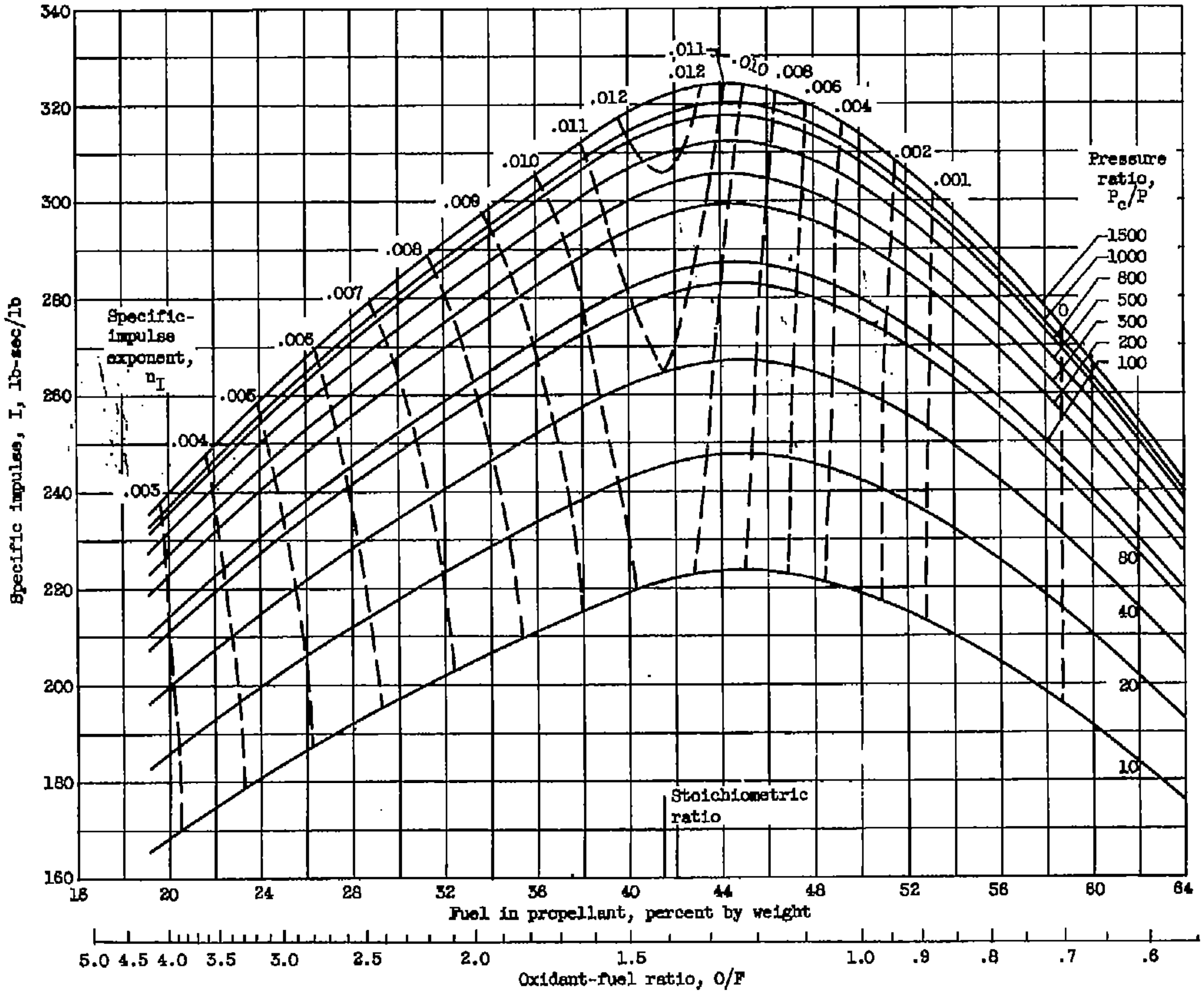
TABLE V. - Concluded. SUMMARY OF COMBUSTION PARAMETERS, CHARACTERISTIC VELOCITY, AND PERFORMANCE FOR EXPANSION TO SEA LEVEL FOR LIQUID AMMONIA WITH LIQUID OXYGEN

Equivalence ratio, R, 2(O)/H	Fuel, percent by weight	Oxidant-to-fuel weight ratio, O/F	Combustion temperature, T_c, °K	Exit temperature, T_e, °K	Characteristic velocity, c*, ft/sec	Characteristic-velocity exponent, n_c*	Entropy, s, $\frac{cal}{(g)(^oK)}$	Area ratio, ε	Coefficient of thrust, C_F	Specific impulse, I, $\frac{(lb)(sec)}{lb}$
Chamber pressure, 600 pounds per square inch absolute; equilibrium composition										
0.40	63.95	0.564	1349	535	4509	0.0000	3.4121	4.888	1.478	207.1
.50	58.67	.705	1784	764	5016	.0000	3.3976	5.134	1.489	232.1
.60	54.19	.845	2171	993	5358	.0000	3.3478	5.369	1.498	249.5
.70	50.34	.986	2503	1219	5596	.0002	3.2836	5.580	1.507	262.0
.80	47.01	1.127	2760	1441	5752	.0017	3.2142	5.795	1.516	270.9
.90	44.09	1.268	2922	1663	5820	.0049	3.1440	6.071	1.530	276.7
.95	42.76	1.339	2963	1778	5817	.0063	3.1093	6.262	1.539	278.3
.975	42.13	1.374	2975	1836	5806	.0068	3.0921	6.379	1.544	278.7
1.00	41.51	1.409	2980	1882	5788	.0069	3.0751	6.484	1.547	278.3
1.10	39.22	1.550	2962	1813	5681	.0060	3.0089	6.369	1.542	272.3
1.20	37.16	1.691	2914	1752	5563	.0052	2.9466	6.312	1.540	266.2
1.50	32.12	2.114	2759	1591	5253	.0039	2.7847	6.156	1.533	250.3
2.00	26.19	2.818	2536	1369	4849	.0024	2.5820	5.908	1.522	229.5
3.00	19.13	4.227	2171	1059	4263	.0007	2.3219	5.558	1.506	199.6
4.00	15.07	5.636	1877	859	3837	.0001	2.1593	5.354	1.497	178.6
5.00	12.43	7.046	1641	720	3510	.0000	2.0451	5.220	1.492	162.8
Chamber pressure, 600 pounds per square inch absolute; frozen composition										
0.40	63.95	0.564	1349	535	4509	0.0000	3.4121	4.888	1.478	207.1
.50	58.67	.705	1784	764	5016	.0003	3.3976	5.134	1.489	232.1
.60	54.19	.845	2171	991	5353	.0005	3.3478	5.366	1.499	249.3
.70	50.34	.986	2503	1201	5573	.0023	3.2836	5.556	1.506	260.9
.80	47.01	1.127	2760	1370	5691	.0056	3.2142	5.693	1.512	267.4
.90	44.09	1.268	2922	1480	5719	.0086	3.1440	5.776	1.515	269.3
.95	42.76	1.339	2963	1509	5703	.0096	3.1093	5.798	1.516	268.7
.975	42.13	1.374	2975	1518	5689	.0099	3.0921	5.804	1.516	268.1
1.00	41.51	1.409	2980	1522	5670	.0100	3.0751	5.808	1.516	267.2
1.10	39.22	1.550	2962	1511	5572	.0094	3.0089	5.804	1.516	262.6
1.20	37.16	1.691	2914	1480	5461	.0085	2.9466	5.786	1.515	257.2
1.50	32.12	2.114	2759	1379	5162	.0067	2.7847	5.722	1.513	242.7
2.00	26.19	2.818	2536	1237	4775	.0048	2.5820	5.626	1.509	223.9
3.00	19.13	4.227	2171	1014	4222	.0024	2.3219	5.461	1.502	197.1
4.00	15.07	5.636	1877	845	3819	.0011	2.1593	5.325	1.497	177.6
5.00	12.43	7.046	1641	715	3503	.0004	2.0451	5.212	1.492	162.4



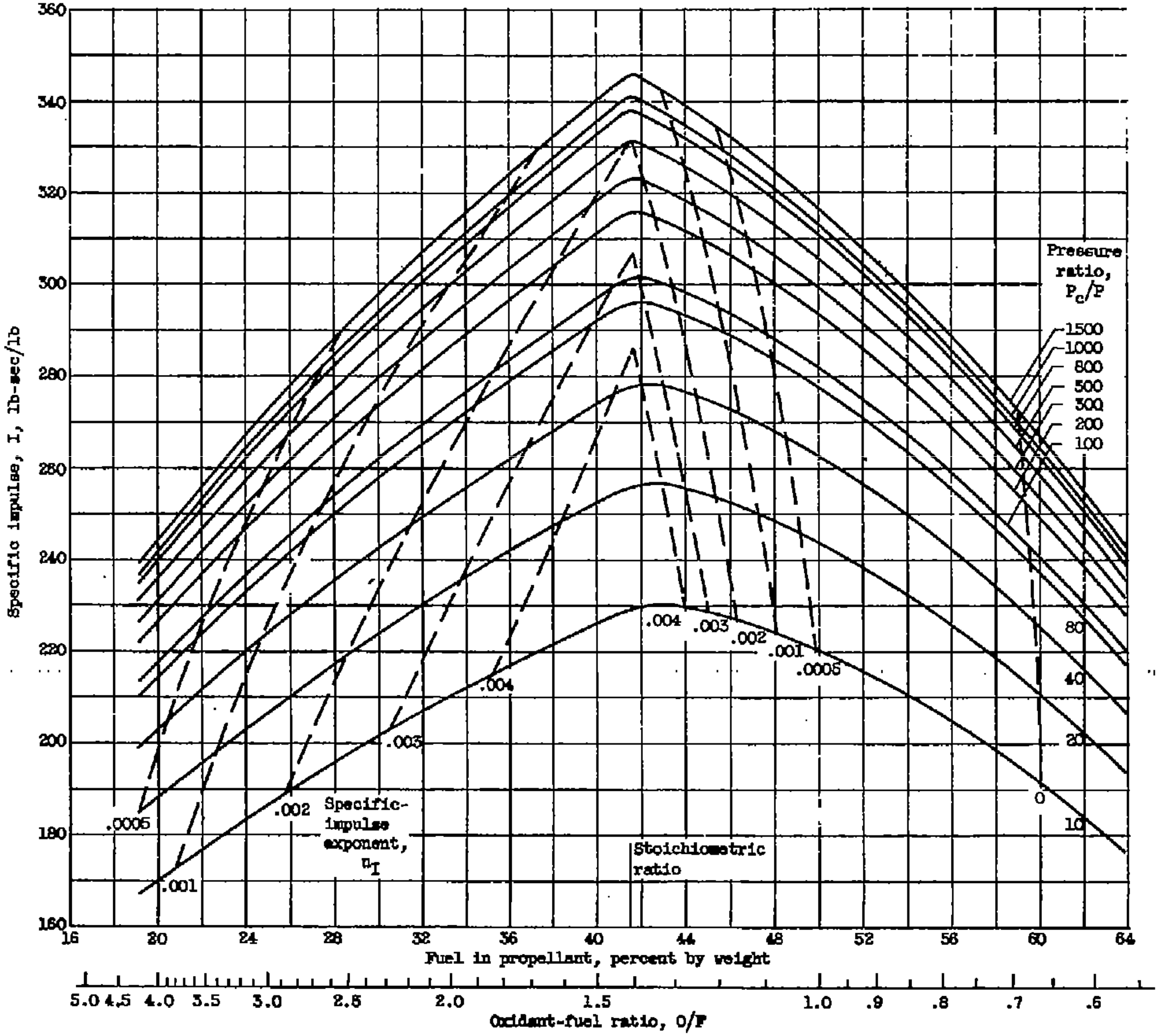
(a) Chamber pressure, 300 pounds per square inch absolute. Equilibrium composition during expansion.

Figure 1. - Theoretical specific impulse of liquid ammonia and liquid oxygen. Isentropic expansion to pressure ratio indicated.



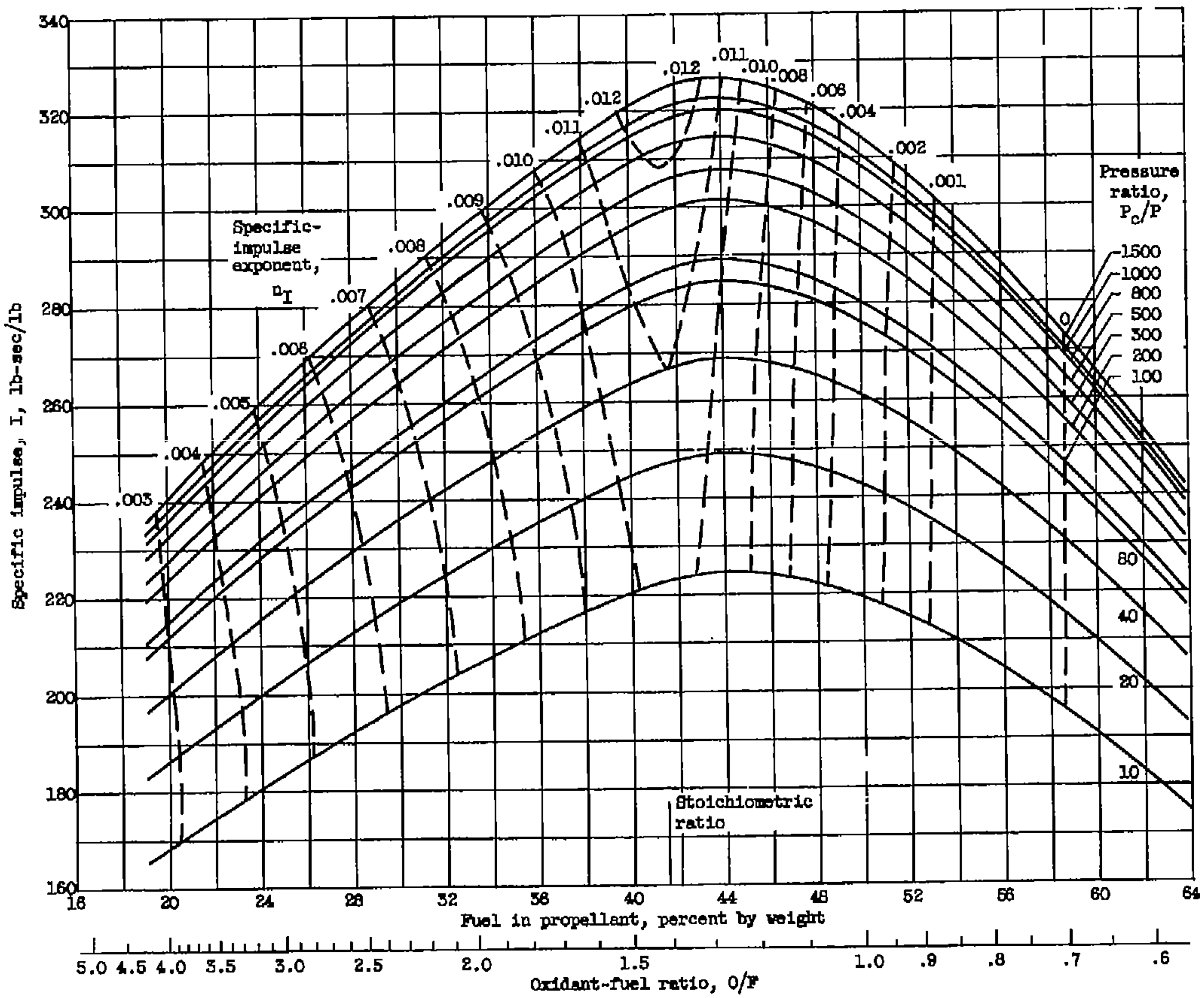
(b) Chamber pressure, 300 pounds per square inch absolute. Frozen composition during expansion.

Figure 1. - Continued. Theoretical specific impulse of liquid ammonia and liquid oxygen. Isentropic expansion to pressure ratio indicated.



(c) Chamber pressure, 600 pounds per square inch absolute. Equilibrium composition during expansion.

Figure 1. - Continued. Theoretical specific impulse of liquid ammonia and liquid oxygen. Isentropic expansion to pressure ratio indicated.



(d) Chamber pressure, 600 pounds per square inch absolute. Frozen composition during expansion.

Figure 1. - Concluded. Theoretical specific impulse of liquid ammonia and liquid oxygen. Isentropic expansion to pressure ratio indicated.

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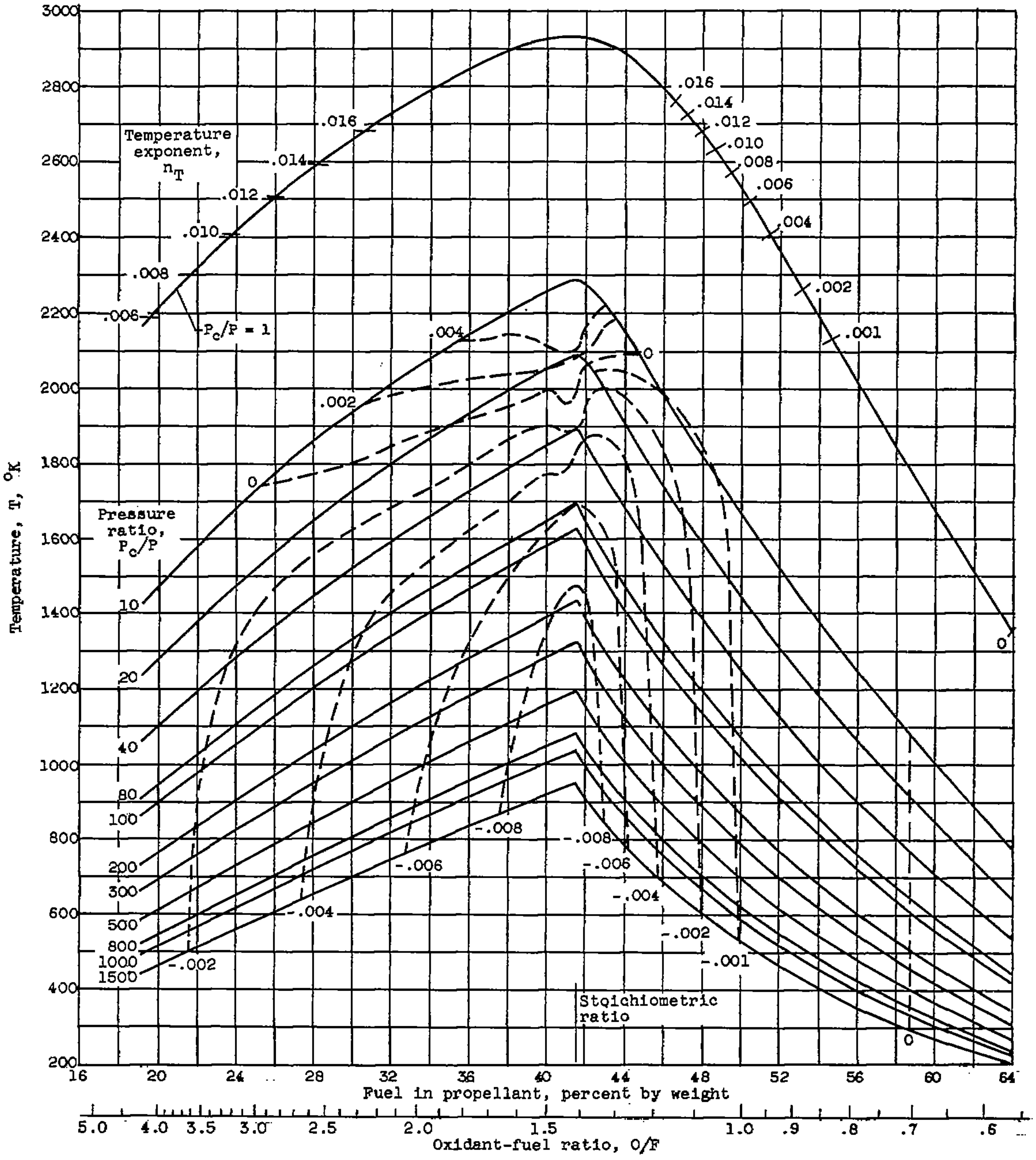

(a) Chamber pressure, 300 pounds per square inch absolute. Equilibrium composition during expansion.

Figure 2. - Theoretical combustion-chamber temperature and nozzle-exit temperature of liquid ammonia and liquid oxygen. Isentropic expansion to pressure ratio indicated.

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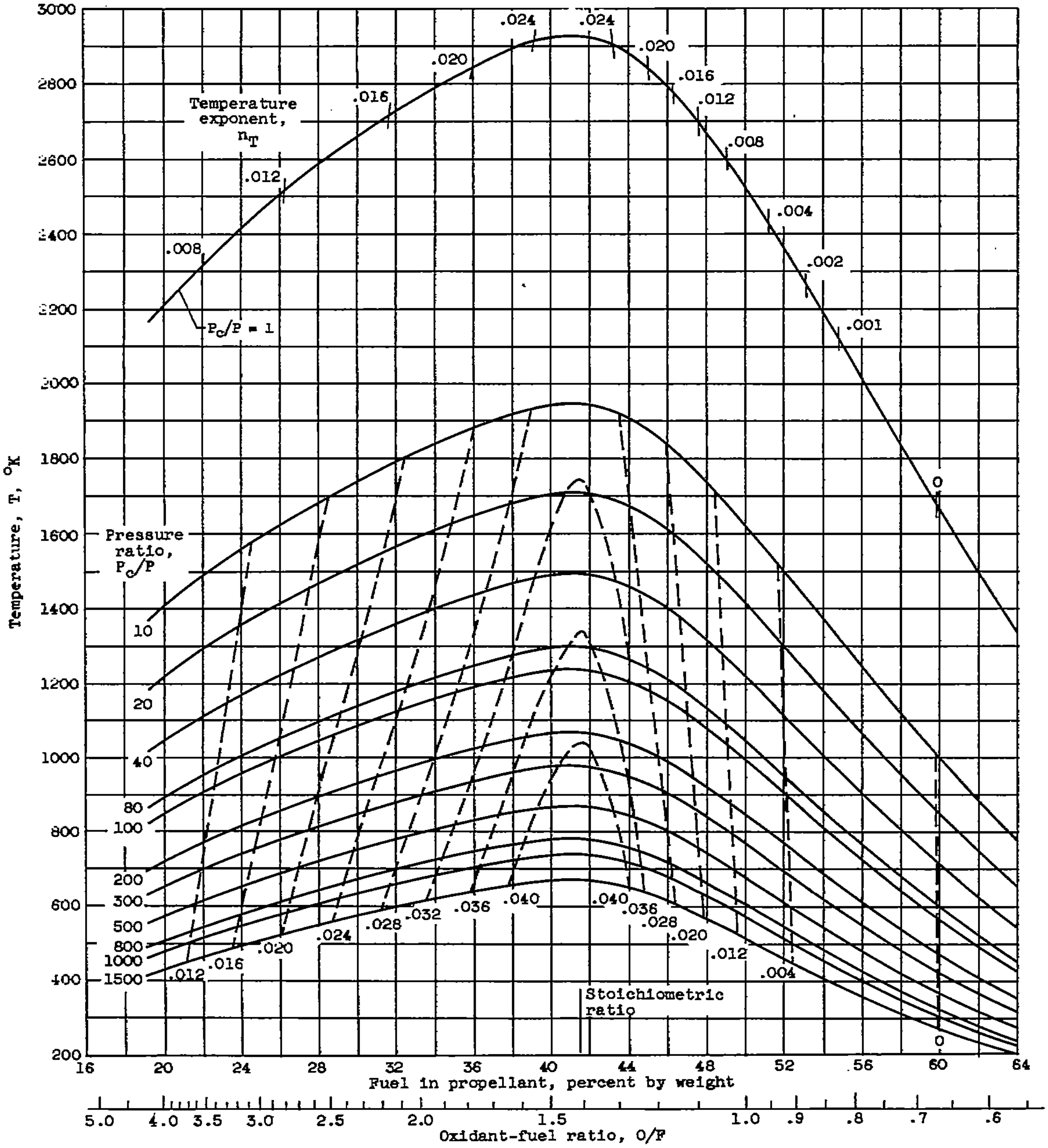
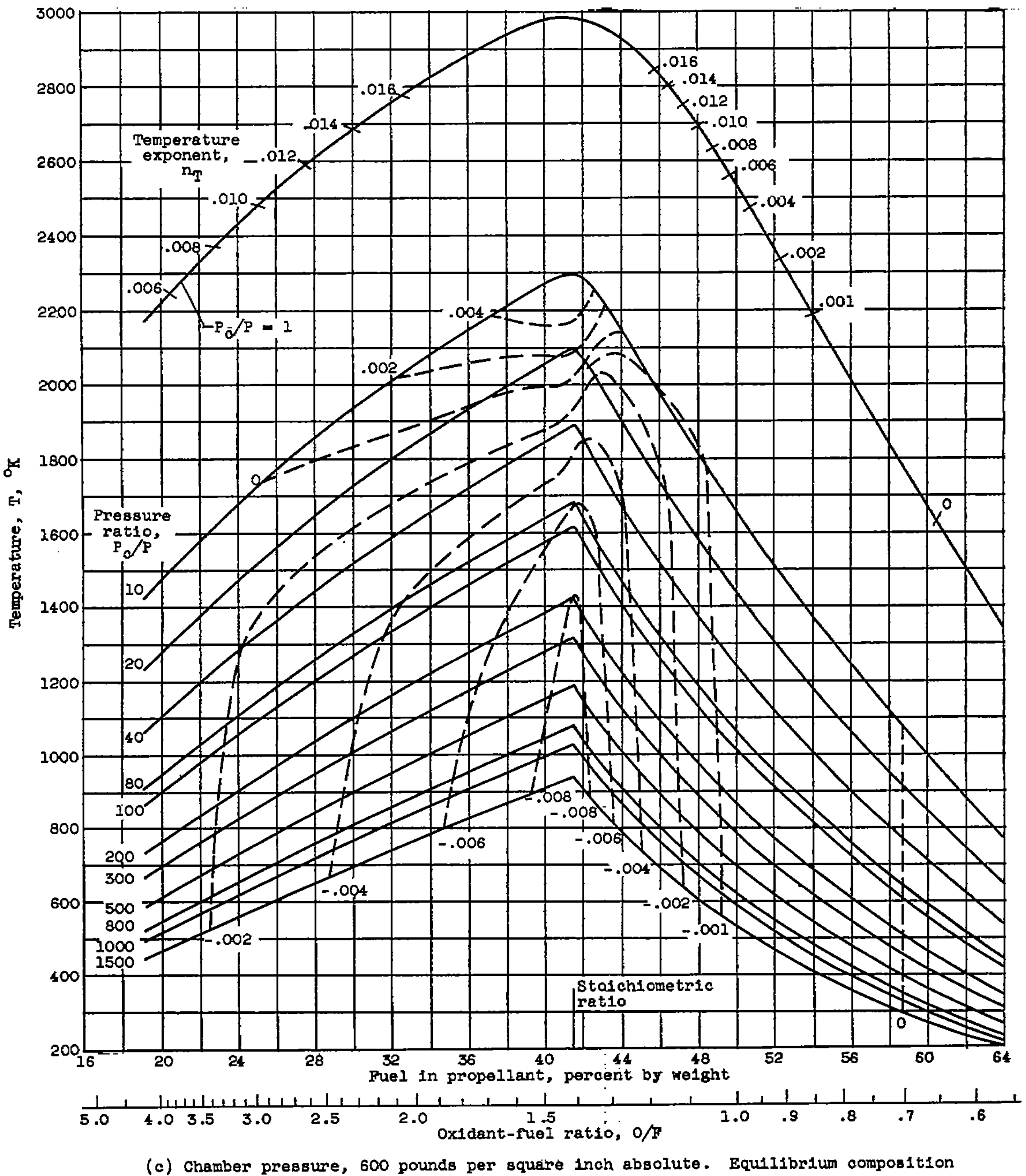


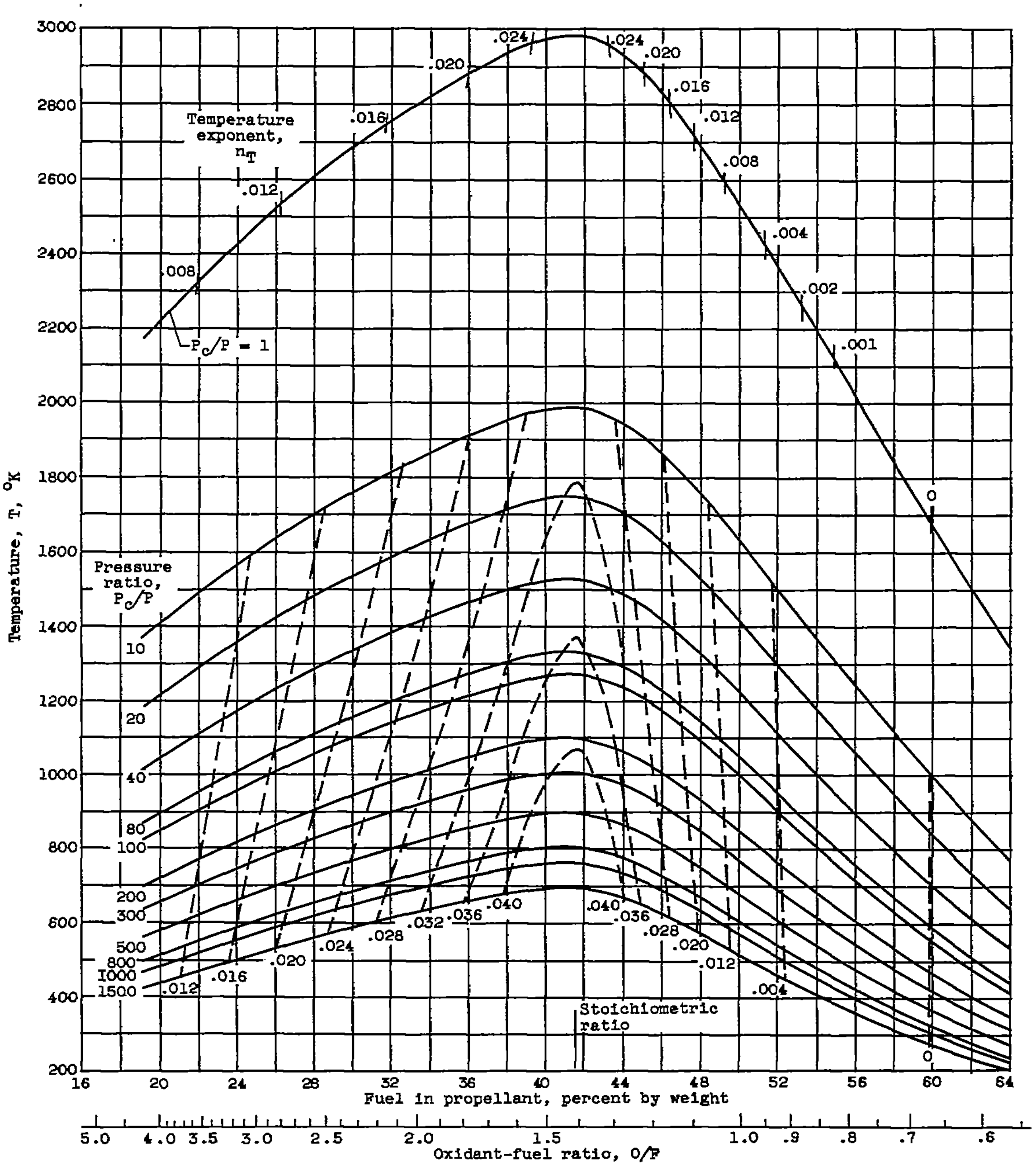
(b) Chamber pressure, 300 pounds per square inch absolute. Frozen composition during expansion.

Figure 2. - Continued. Theoretical combustion-chamber temperature and nozzle-exit temperature of liquid ammonia and liquid oxygen. Isentropic expansion to pressure ratio indicated.



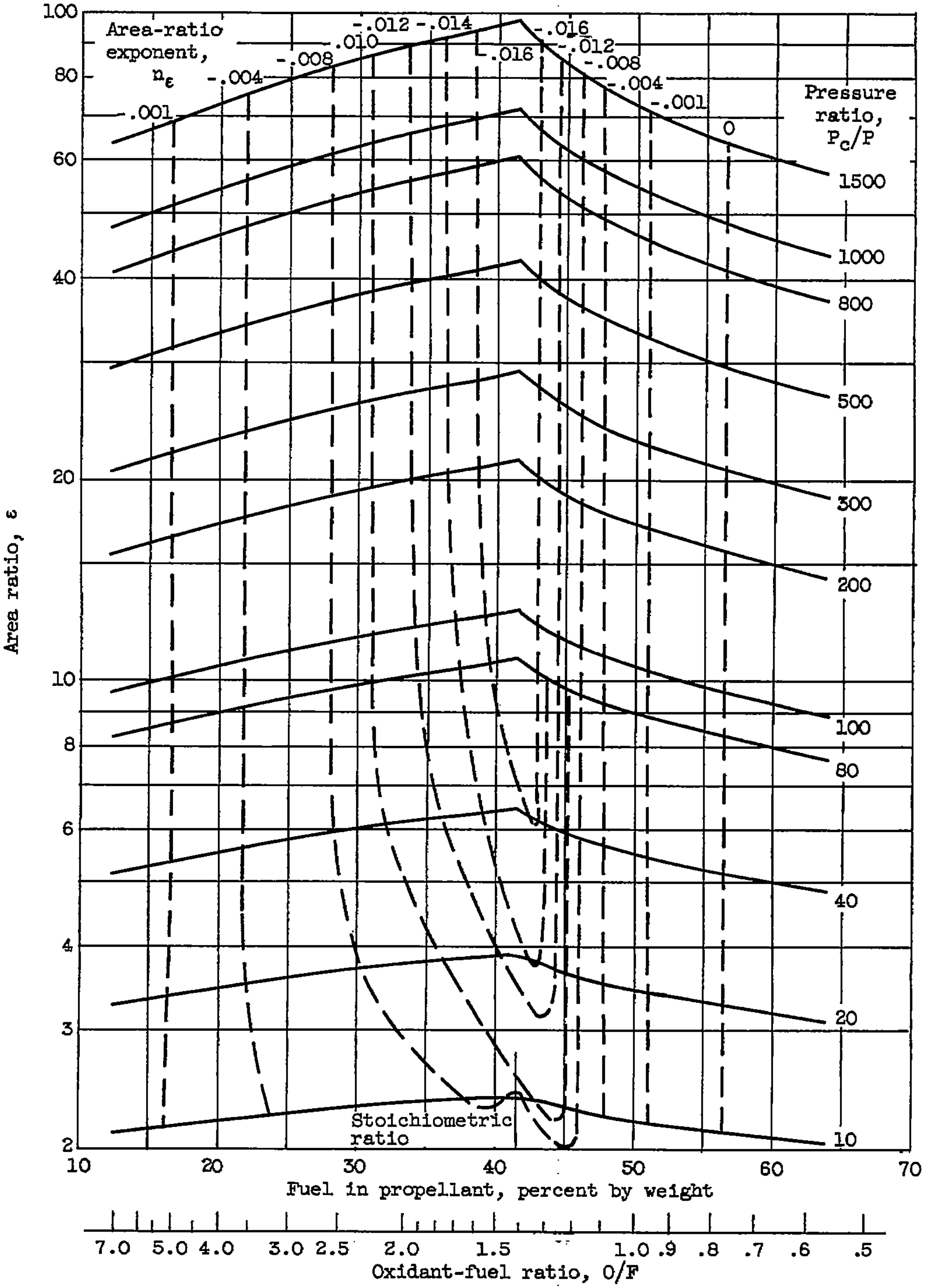
(c) Chamber pressure, 600 pounds per square inch absolute. Equilibrium composition during expansion.

Figure 2. - Continued. Theoretical combustion-chamber temperature and nozzle-exit temperature of liquid ammonia and liquid oxygen. Isentropic expansion to pressure ratio indicated.



(d) Chamber pressure, 600 pounds per square inch absolute. Frozen composition during expansion.

Figure 2. - Concluded. Theoretical combustion-chamber temperature and nozzle-exit temperature of liquid ammonia and liquid oxygen. Isentropic expansion to pressure ratio indicated.



(a) Chamber pressure, 300 pounds per square inch absolute. Equilibrium composition during expansion.

Figure 3. - Theoretical ratio of nozzle area to throat area for liquid ammonia and liquid oxygen. Isentropic expansion to pressure ratio indicated.

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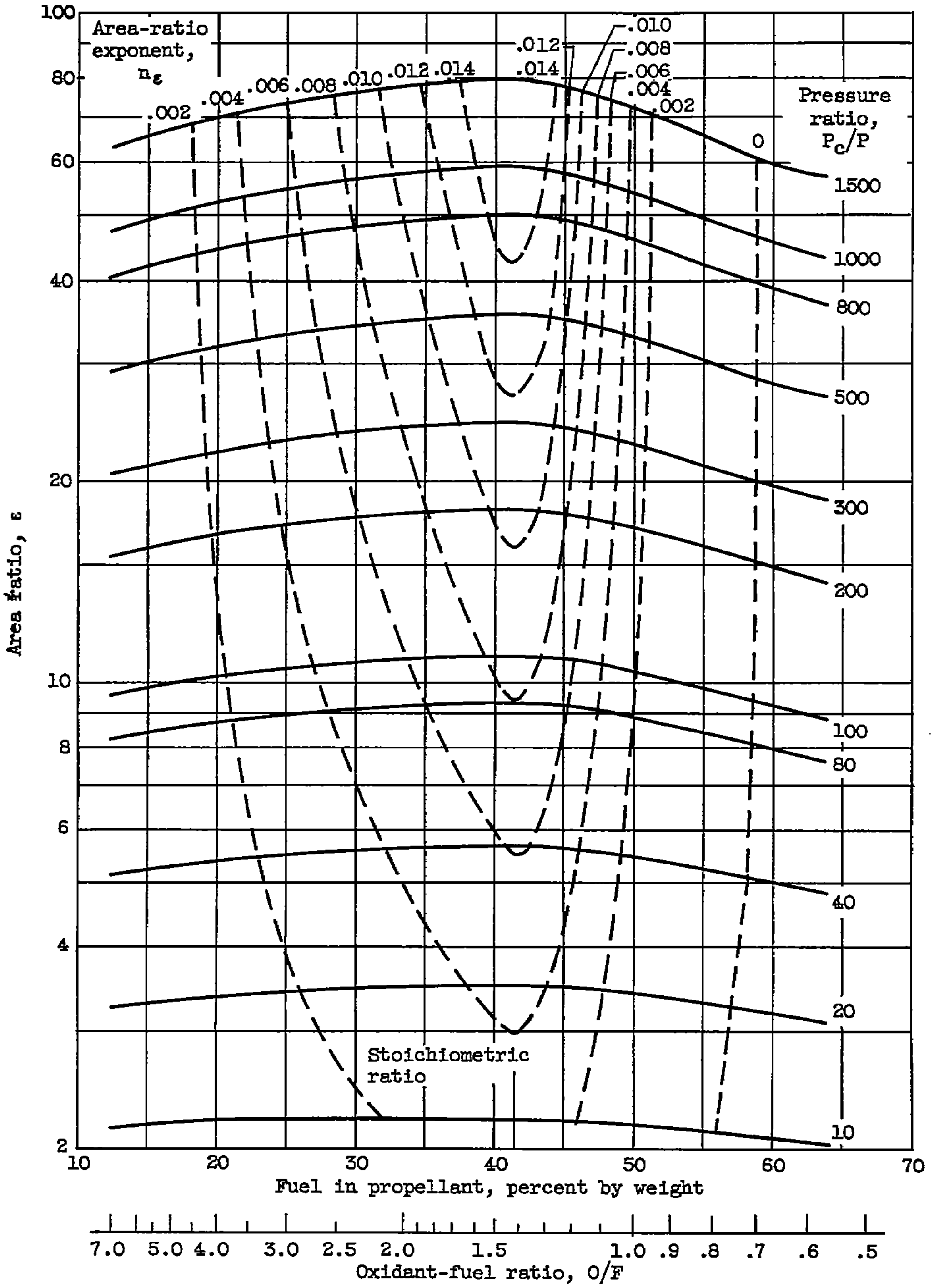
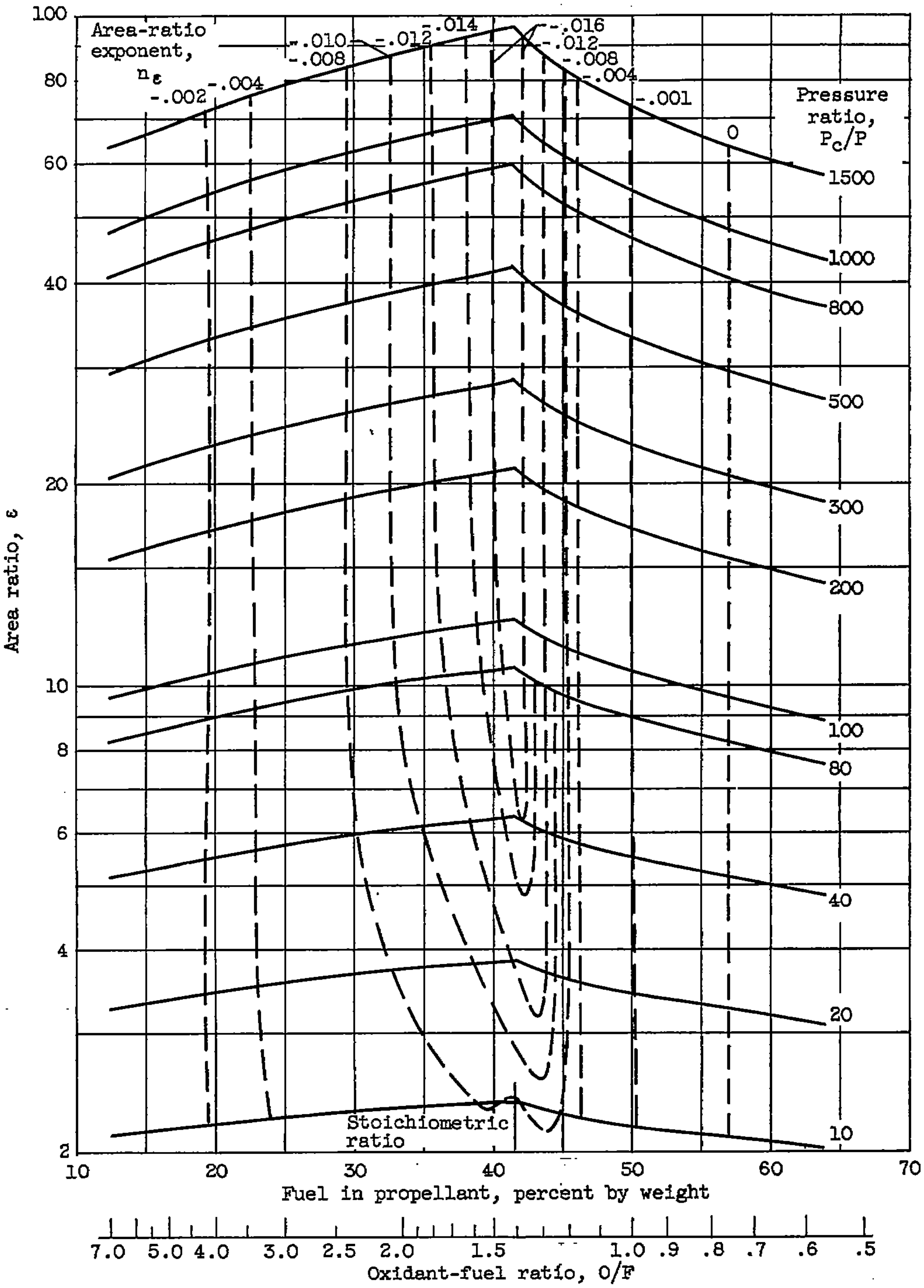


(b) Chamber pressure, 300 pounds per square inch absolute. Frozen composition during expansion.

Figure 3. - Continued. Theoretical ratio of nozzle area to throat area for liquid ammonia and liquid oxygen. Isentropic expansion to pressure ratio indicated.



(c) Chamber pressure, 600 pounds per square inch absolute. Equilibrium composition during expansion.

Figure 3. - Continued. Theoretical ratio of nozzle area to throat area for liquid ammonia and liquid oxygen. Isentropic expansion to pressure ratio indicated.

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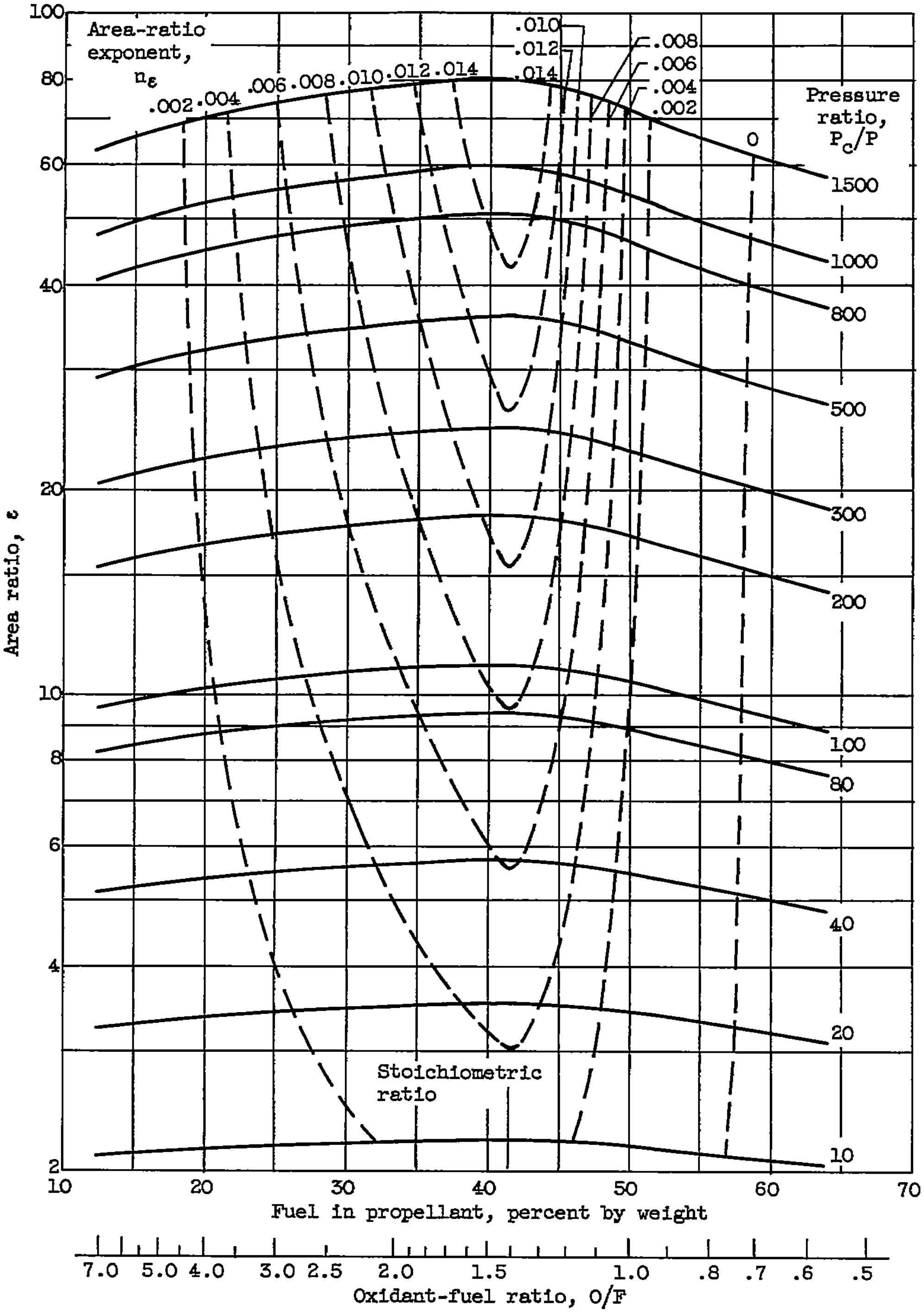
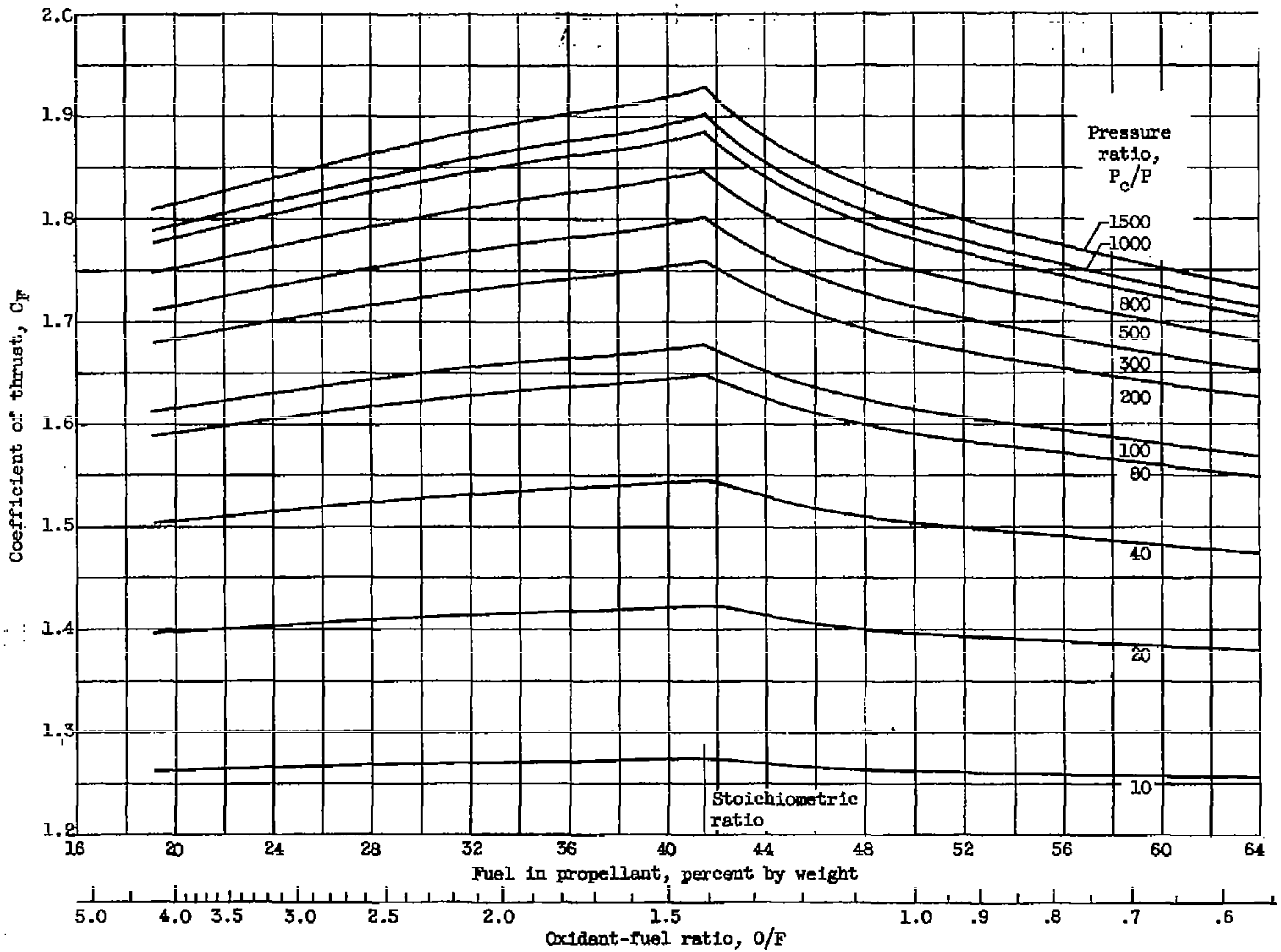


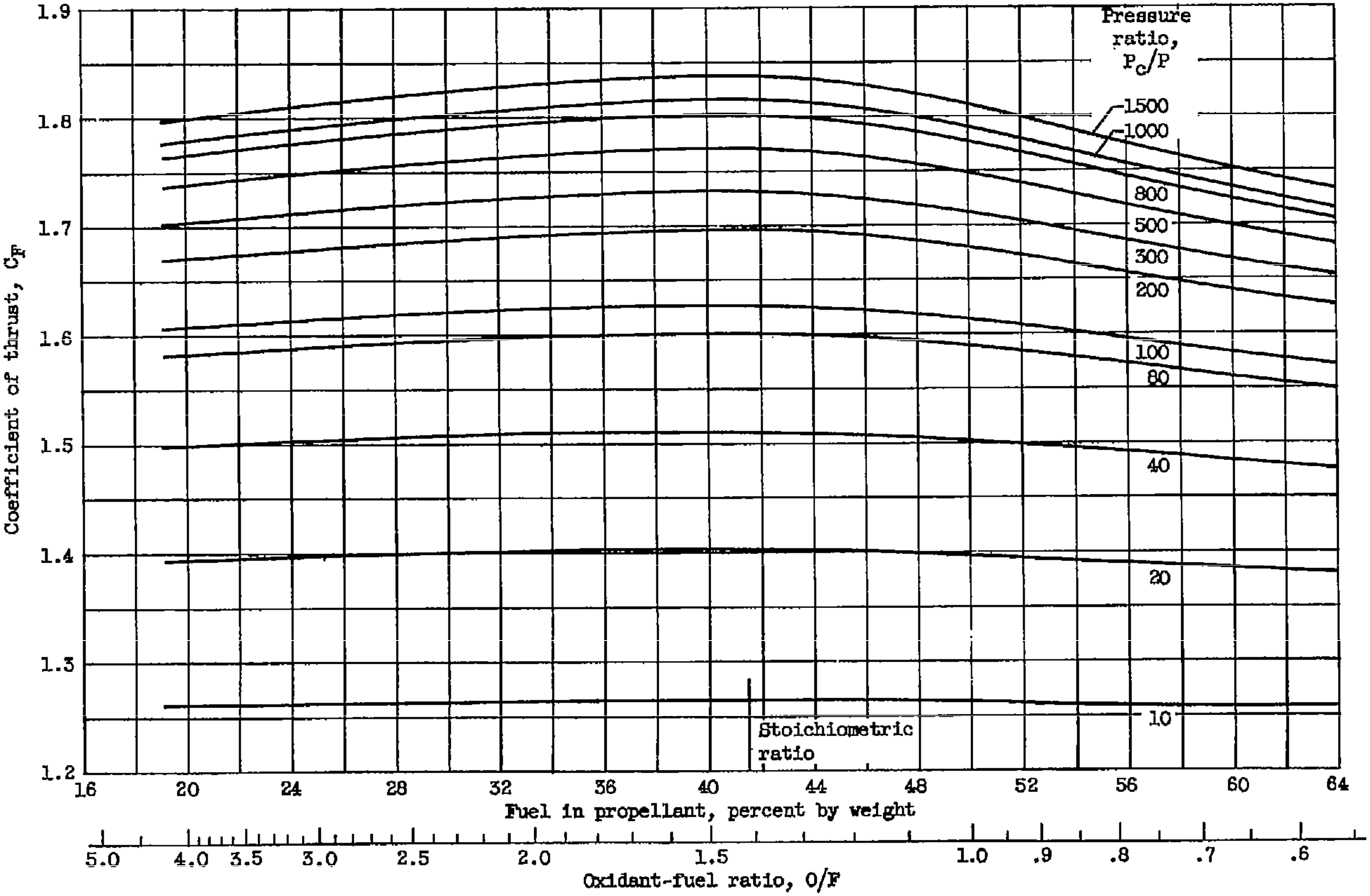
(d) Chamber pressure, 600 pounds per square inch absolute. Frozen composition during expansion.

Figure 3. - Concluded. Theoretical ratio of nozzle area to throat area for liquid ammonia and liquid oxygen. Isentropic expansion to pressure ratio indicated.



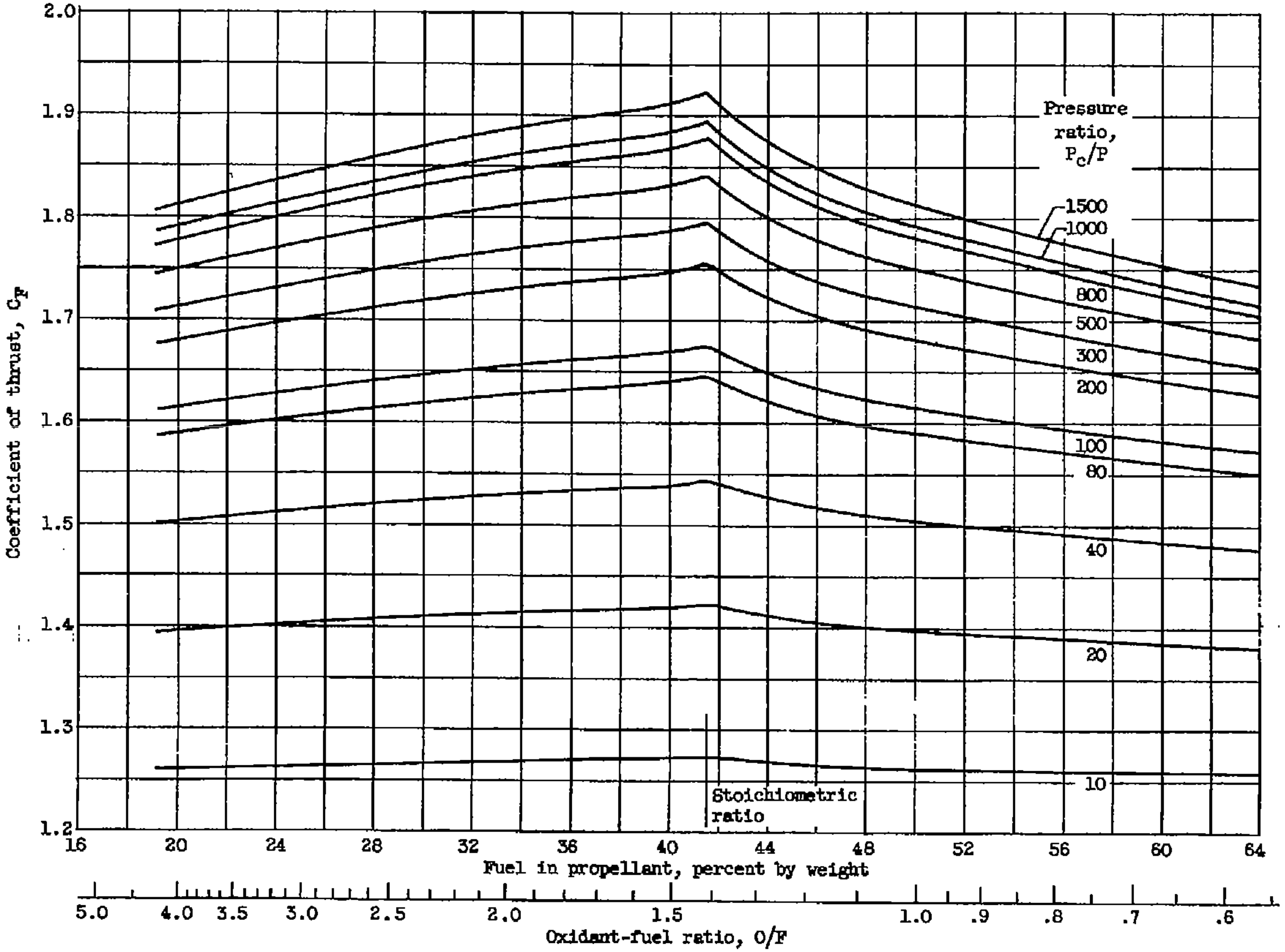
(a) Chamber pressure, 300 pounds per square inch absolute. Equilibrium composition during expansion.

Figure 4. - Theoretical coefficient of thrust of liquid ammonia and liquid oxygen. Isentropic expansion to pressure ratio indicated.



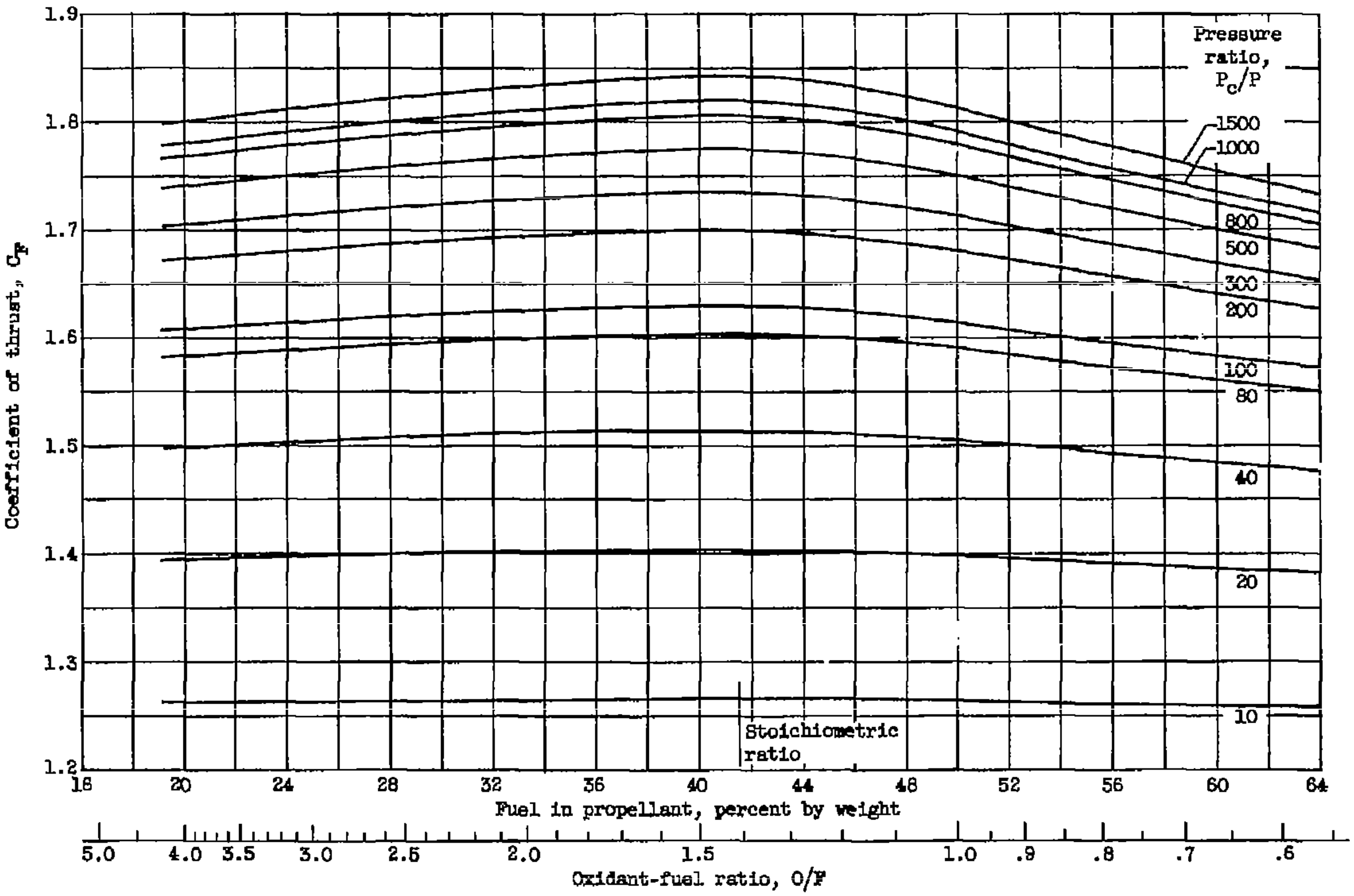
(b) Chamber pressure, 300 pounds per square inch absolute. Frozen composition during expansion.

Figure 4. - Continued. Theoretical coefficient of thrust of liquid ammonia and liquid oxygen. Isentropic expansion to pressure ratio indicated.



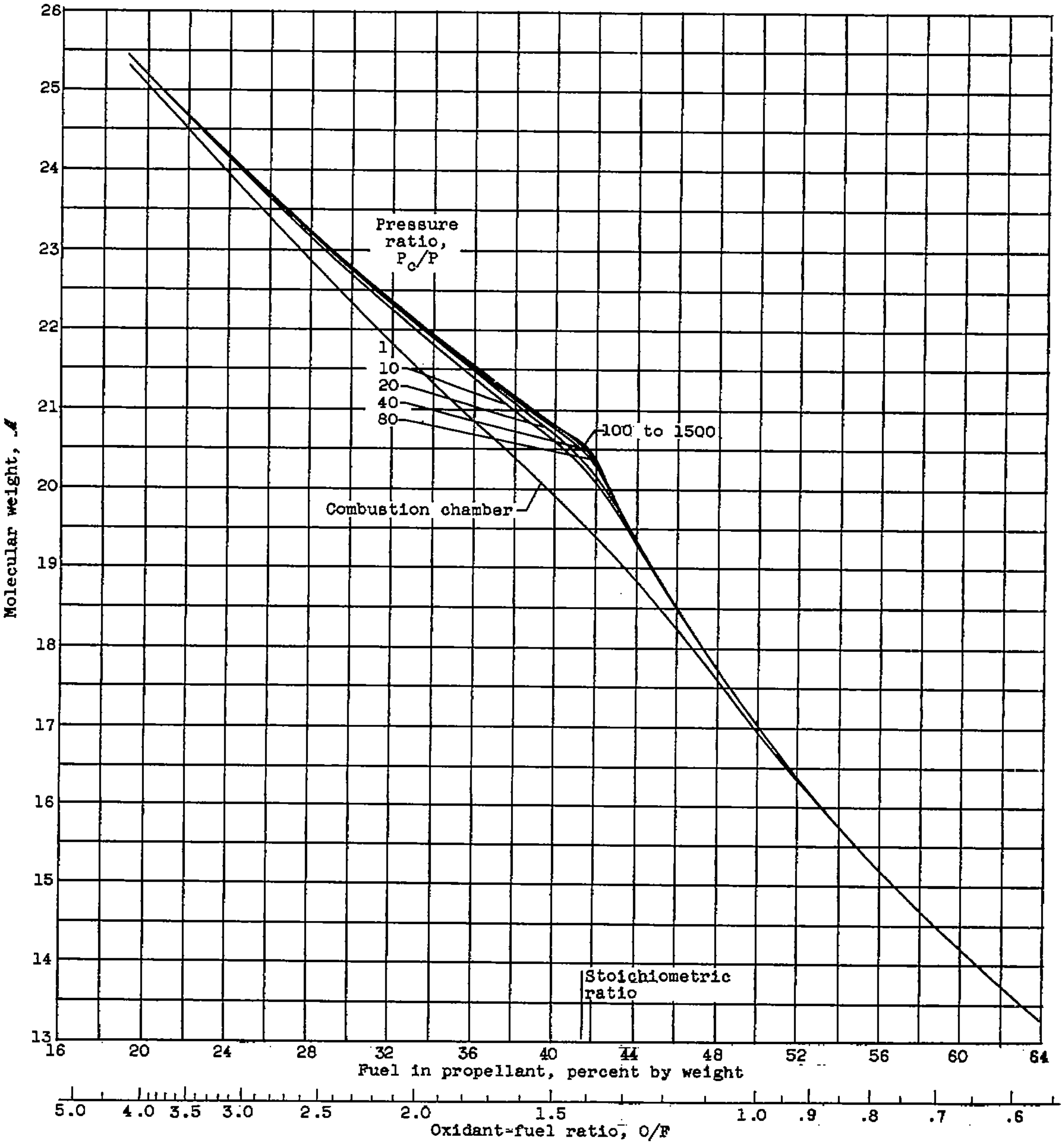
(c) Chamber pressure, 600 pounds per square inch absolute. Equilibrium composition during expansion.

Figure 4. - Continued. Theoretical coefficient of thrust of liquid ammonia and liquid oxygen. Isentropic expansion to pressure ratio indicated.



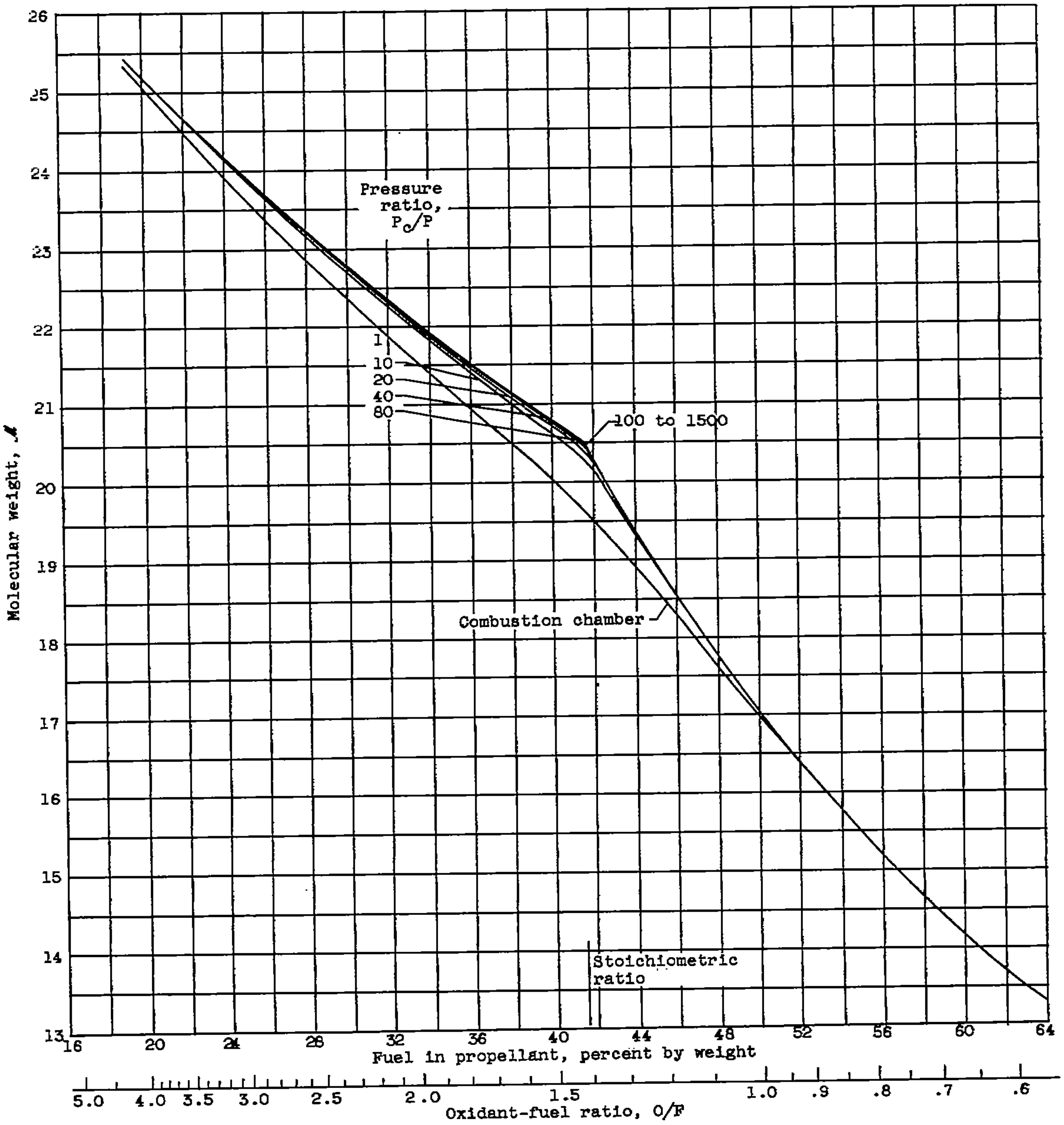
(d) Chamber pressure, 600 pounds per square inch absolute. Frozen composition during expansion.

Figure 4. - Concluded. Theoretical coefficient of thrust of liquid ammonia and liquid oxygen. Isentropic expansion to pressure ratio indicated.



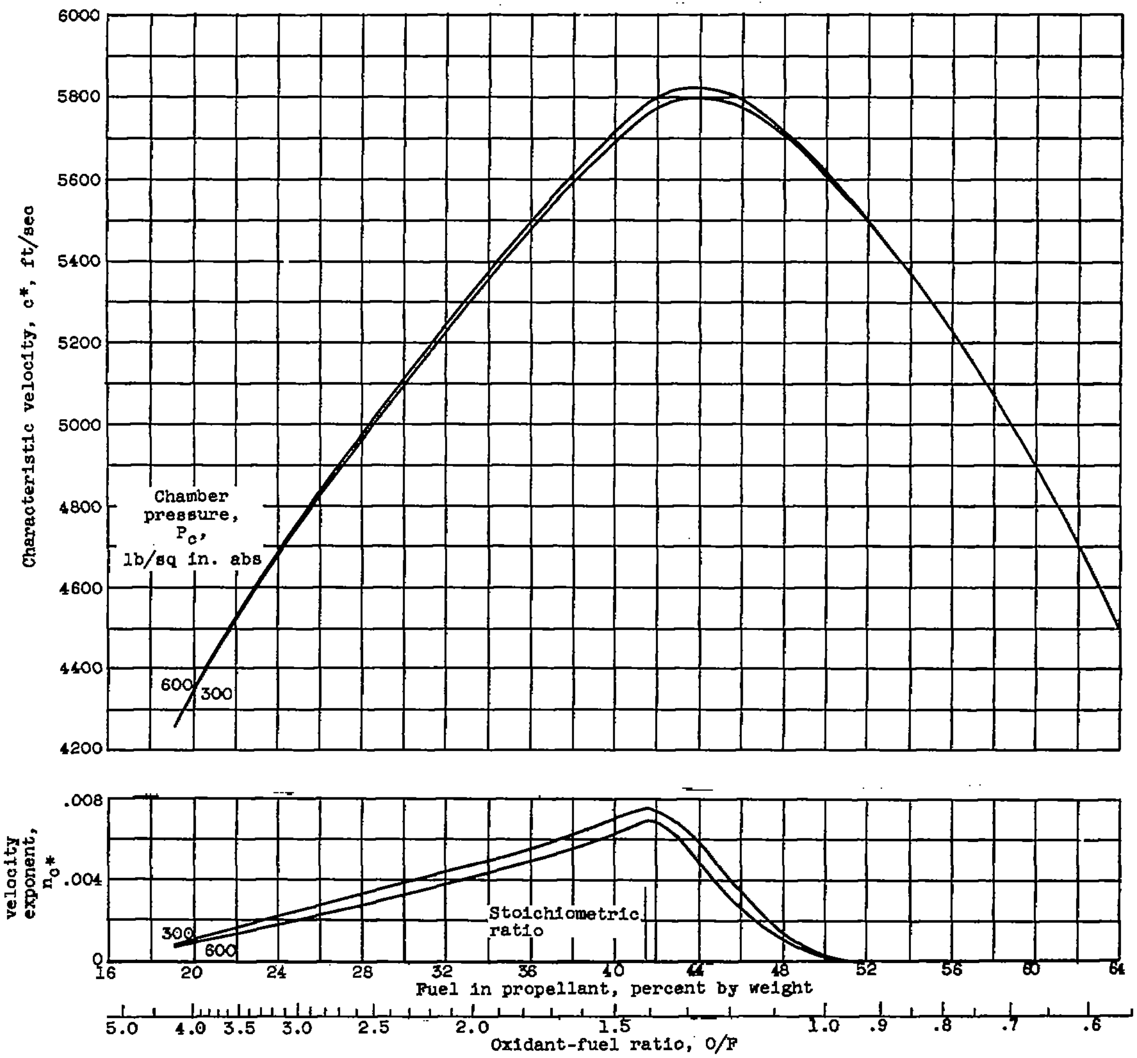
(a) Chamber pressure, 300 pounds per square inch absolute.

Figure 5. - Theoretical molecular weight of liquid ammonia and liquid oxygen assuming equilibrium composition during isentropic expansion to pressure ratio indicated.



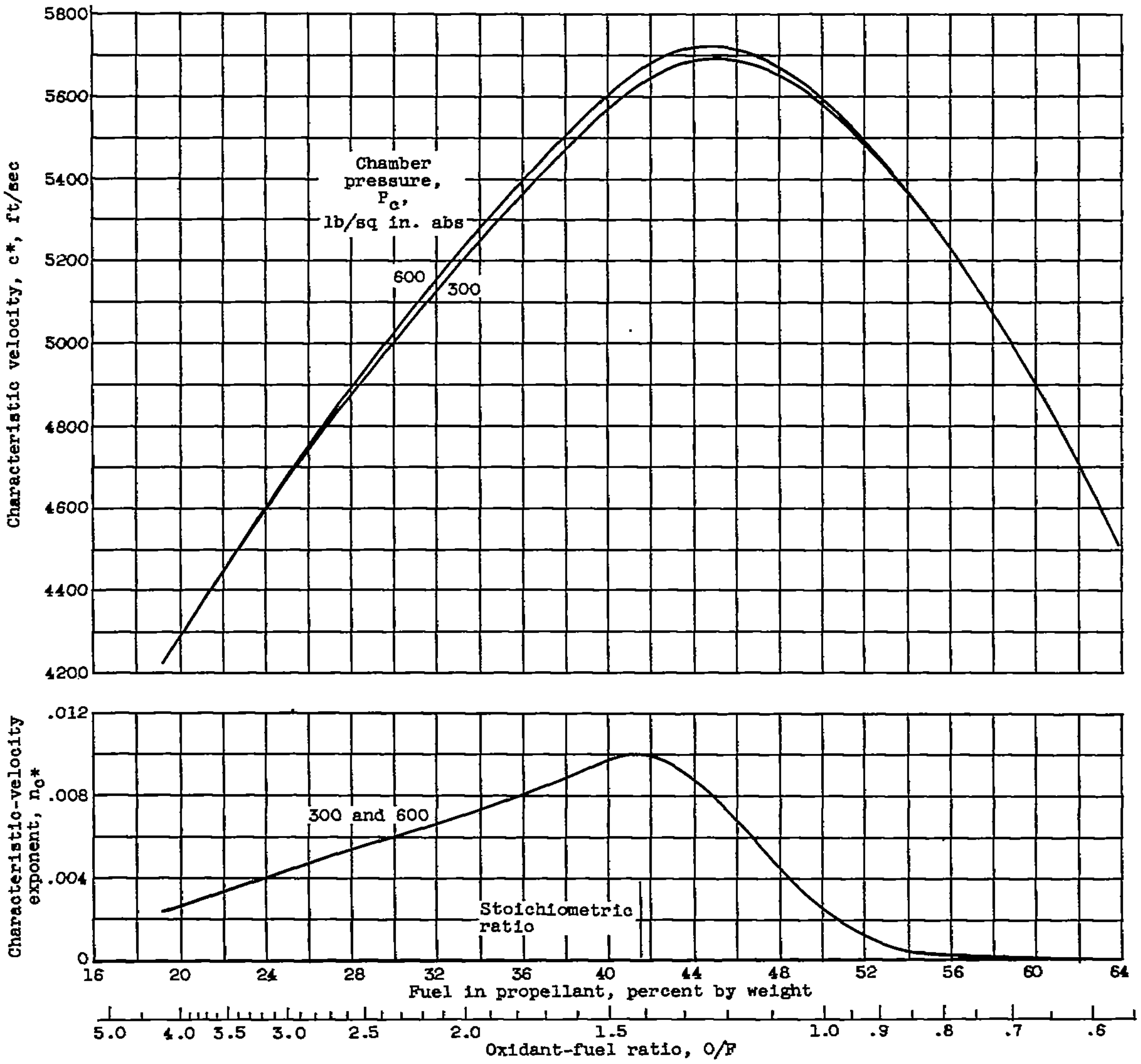
(b) Chamber pressure, 600 pounds per square inch absolute.

Figure 5. - Concluded. Theoretical molecular weight of liquid ammonia and liquid oxygen assuming equilibrium composition during isentropic expansion to pressure ratio indicated.



(a) Equilibrium composition during expansion.

Figure 6. - Theoretical characteristic velocity of liquid ammonia and liquid oxygen.



(b) Frozen composition during expansion.

Figure 6. - Concluded. Theoretical characteristic velocity of liquid ammonia and liquid oxygen.

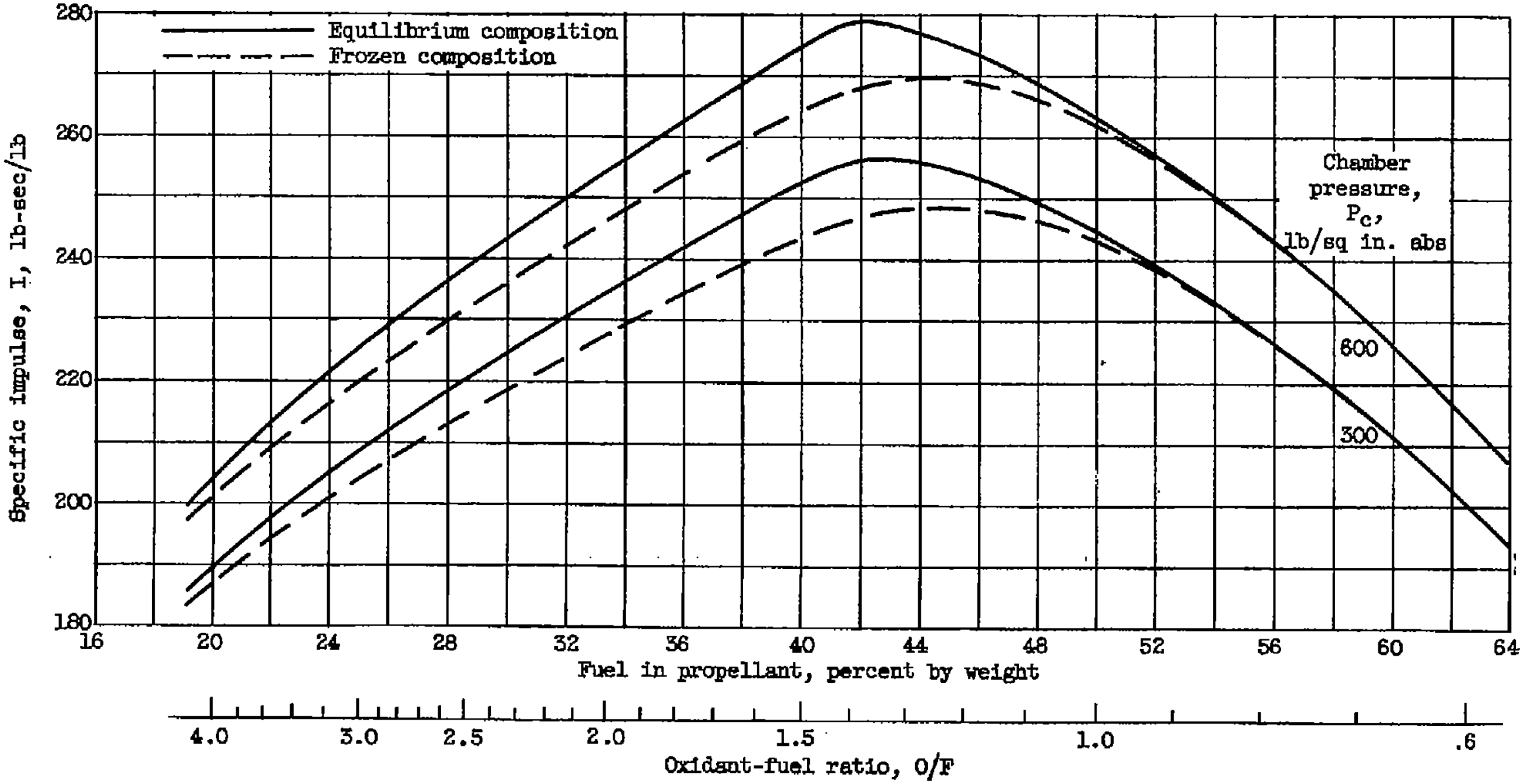


Figure 7. - Theoretical specific impulse for liquid ammonia with liquid oxygen. Isentropic expansion to 1 atmosphere from chamber pressure indicated.